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14 INTERNATIONAL CONGRESS OF ENTOMOLOGY
CANBERRA 22–30 AUGUST 1972

ABSTRACTS

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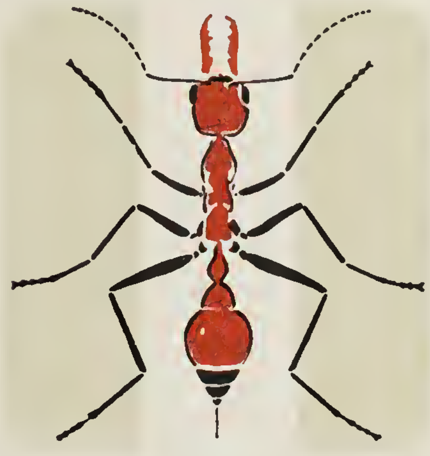

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ABSTRACTS

Sponsored by:

The Australian Academy of Science,
The Australian Entomological Society,
and held at the Australian National University
Canberra
22-30 August 1972

THE CONGRESS SYMBOL

Myrmecia gulosa (Fabricius), the red bulldog ant, symbol of the Congress, was described in the classic "Systema Entomologiae". In that work, Fabricius published the first formal descriptions of Australian insects naming some 210 species collected by Banks and Solander in 1770, during Cook's first voyage around the world.

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ABSTRACTS

SCIENTIFIC PROGRAMME

CONGRESS SYMPOSIA

SYMPOSIUM NO. 1

CLASSIFICATION AND PHYLOGENY

ORGANIZER: E.B. BRITTON

CLASSIFICATION AND PHYLOGENY

W.W. Moss

Department of Entomology, Academy of Natural Sciences, Philadelphia, U.S.A.

Taxonomists subsequent to Darwin have tried to recognize classifications in an evolutionary context, and to interpret their findings with respect to inferred phyletic history. Such activities have a considerable intellectual challenge and appeal, but tend to operate under a variety of theoretical and methodological assumptions which must be clarified and kept in mind. An argument can be made for the total exclusion of phyletic studies from the domain of scientific inquiry, so it is necessary for taxonomists to be aware of potential strengths and weaknesses in such approaches, in order to justify their inclusion in the process and product of classification.

NATURE'S HIERARCHY AND THE BIOLOGICAL REFERENCE SYSTEM

L. Brundin

Swedish Museum of Natural History, Stockholm, Sweden

Because of the insight that the splitting of mother species into daughter species has been the main model of speciation and the reason for the present biotic diversity, we are forced to admit that nature has created a system of its own that is in principle hierarchic. The units of this truly phylogenetic system are the biological species and the strictly monophyletic species groups all of which have individuality and reality. Hence, it is a matter of logic to conclude that dispersal and evolutionary change have taken place in time and space within orderly hierarchic sequences of successively subordinate monophyletic groups. Consequently, we are able to express nature's hierarchy only through a system in which every group is given the same rank as its sister group. Only such a system can function adequately as a general biological reference system.

It is obvious that a deeper penetration of causal biology is possible only via a reconstruction of nature's own hierarchy, and operation with the units forming that hierarchy. Such a reconstruction has to be based on the phylogenetic-biogeographical synthesis, including establishment of strict monophyly by the exclusive use of inferred synapomorphy and, also, the search for sister groups by additional use of geographical replacement.

Consideration of the quantitative aspect (phenetic distance, amount of change) leads to construction of a contradictory hierarchy, consisting partly of non-monophyletic groups that lack reality. Such a system, which is inconsistent with nature's hierarchy and the history, both in time and space, of the evolutionary units, cannot function adequately as a general reference system of causal biology.

SCIENCE AND NON-SCIENCE IN SYSTEMATICS

L.A.S. Johnson

Royal Botanic Gardens, Sydney, N.S.W., Australia

Systematics differs from other pursuits of scientists in that its essence (to many, its chief aim) is classification of objects, whereas science generally classifies processes - event-sequences. Without a theoretical framework there is no science. Phenetic classification has no framework of biological theory (mathematical and philosophical theories of classification concern methodology, not biology). Phyletic reconstruction (cladistics) has a basis in theory but is often impracticable and its hierarchical structure is in general not compatible with that demand of useful taxonomic classifications. These deficiencies are inherent and there is no more a soluble general taxonomic problem than there is a soluble problem of making 2 equal 3. Thus classification is no science but an art. An art has no "truth", in the scientific sense, but does have variously satisfying and useful products. By facing this we save futile argument and effort. The systematist's work, however, should embrace a great deal of science, for systematics is a co-ordinative subject, drawing upon numerous branches of biology the scientific status of which needs no defence.

SYMPOSIUM NO. 2

GENETIC ANALYSIS OF SPECIATION MECHANISMS

ORGANIZER: M.J.D. WHITE

GENETIC CHANGE AND SPECIATION IN THE VIRILIS GROUP OF *DROSOPHILA*

L.H. Throckmorton

Department of Biology, University of Chicago, Chicago, Illinois, U.S.A.

Using acrylamide gel electrophoresis, genetic differentiation was assessed at about a dozen loci for each of ten species of the virilis group of *Drosophila*. Populations were sampled from throughout the range of each species where possible. Given this information, information from reproductive behaviour and information from the salivary gland chromosome phylogeny, the qualitative genetic makeup of gene pools of extant species could be specified and the makeup of ancestral gene pools could be inferred. Changes in ancestral gene pools could be traced through time and followed through various speciation events as these occurred in the past. Gene pool changes could be related to ecological shifts and to changes in distribution, including two colonizations of the new world from the old. The average speciation event involved reduction of genetic variability, and no more change was involved than is involved during introspecific adjustments of local populations to local environments. In several cases the interspecific differences are markedly less than intraspecific differences. The two major lineages evolved at different rates, with the lineage exploiting novel ecological opportunity evolving at approximately twice the rate of the one remaining in the ancestral habitat. There is thus no constant rate of biochemical evolution and no evidence for extensive reorganization of gene pools during speciation. These data also provide indirect evidence for maintenance of protein polymorphisms through natural selection, since at one-fourth of the loci polymorphisms persisted in one or both lineages from the time of the group ancestor to the present.

MECHANISMS OF SYMPATRIC HOST RACE FORMATION IN THE TRUE FRUIT FLIES (TEPHRITIDAE)

G.L. Bush

Department of Zoology, University of Texas, Austin, Texas, U.S.A.

Recent behaviour and genetic studies on stenophagous and monophagous representatives of two tephritid genera, *Rhagoletis* and *Procecidochares* indicate that reproductively isolated populations on different host plants can evolve within a few generations. As mating in these flies occurs on the host plant, the primary isolating mechanism is host preference. Hybridization studies indicate host recognition and selection is controlled by a single gene. Thus gene flow can be drastically reduced or eliminated between a newly established host race and it's parent population as a result of a mutation at a single host recognition locus. Furthermore, allozyme studies have shown that no major genetic revolution has occurred in recently established host races. All evidence therefore indicated that reproductively isolated host races can evolve sympatrically without prior periods of geographic isolation as a result of simple genetic changes. Similar patterns of sympatric speciation may be wide spread in other phytophagous and parasitic insects.

CHROMOSOMAL EVOLUTION AND SPECIATION IN *DIDYMURIA VIOLESCENS*

Elysse M. Craddock

Department of Genetics, University of Hawaii, Honolulu, Hawaii, U.S.A.

Speciation may often involve chromosomal differentiation as an integral part of the process. Because of the inherent features of structural chromosomal rearrangements, the initial establishment of such differences within a species could provide the necessary conditions for the development of full reproductive barriers. The cytological discontinuities found in racial patterns of chromosome variation may become secondarily reinforced, and the primary chromosomal isolation might be supplemented or replaced by other non-chromosomal devices. In the Australian phasmatid *Didymuria violescens* (Leach), the existence of ten chromosome races with widely different karyotypes favours further genetic divergence, which may eventually result in full speciation. The races vary in diploid chromosome number from 26 to 40, in sex-chromosome mechanism and in other aspects of their karyotypes unrelated to numerical or sex-chromosome differences. They are not morphologically distinguishable. Comparisons of their karyotypes, and analyses of the meiotic pairing relationships in interracial hybrids, have confirmed many of the autosome - autosome and autosome - sex-chromosome translocation differences between races. These data, taken together with the racial distribution patterns, suggest an interpretation of the chromosomal and geographic sequence of events in the evolution of this species. Present reproductive isolation between races is judged to be incomplete, in view of the partial fertility of the chromosome hybrids found in the narrow zones of overlap between adjacent races. The situations in *Didymuria violescens* and in other similarly cytologically differentiated taxa have many implications for concepts of speciation mechanisms.

SPECIATION IN THE AUSTRALIAN MORABINE GRASSHOPPERS - TAXONOMY AND ECOLOGY

K.H.L. Key

Division of Entomology, CSIRO, Canberra, A.C.T., Australia

The endemic Australian subfamily Morabinae, of the family Eumastacidae (Orthoptera), comprises some 240 species of attenuate, apterous grasshoppers of low vagility. The group is distributed over almost the whole country, but the ranges of individual species are small. Species in different genera or species groups are commonly broadly sympatric; on the other hand, closely related species, and races within species, are often "parapatric", making contact in very narrow "tension zones". In the latter case there is no pre-mating reproductive barrier, but hybrids are non-viable or infertile (species), or show diminished viability or fertility (races). The situation is interpreted as resulting from the evolutionary divergence of two populations under conditions of temporary allopatry (or "microallopatry"), followed by their secondary contact and reproductive confrontation in the tension zone, the ultimate location of which represents the smoothed resultant of year-to-year oscillations of the line along which ecological conditions confer equal fitness upon the competing homozygotes.

SPECIATION IN THE AUSTRALIAN MORABINAE GRASSHOPPERS - CYTOGENETIC EVIDENCE

M.J.D. White

Department of Genetics, University of Melbourne, Melbourne, Vic., Australia

Most species of Morabine grasshoppers have unique karyotypes which differ from those of their closest relatives as a result of chromosomal rearrangements of one kind or another. A total of 61 different changes of chromosome number (39 decreases and 22 increases) have been identified in the phylogeny of the group. Not a single one of these is known to exist in a state of balanced polymorphism over a wide geographic area, but a number are polymorphic in very narrow zones of overlap between parapatric tax. Heterozygotes for such rearrangements generally have their fecundity reduced to some extent by anomalies of chromosomal pairing or segregation at meiosis. There is accordingly presumptive evidence that chromosomal rearrangements may have played a primary role as divisive agents in the speciation of at any rate some morabine grasshoppers. The suggestion is that this took place according to the 'stasipatric' model, with chromosomal rearrangements arising within the area occupied by the ancestral species and spreading out from their point of origin, so as to eventually occupy a district territory, with exclusion of the original chromosome or chromosomes.

SYMPOSIUM NO. 3

THE USE OF GENETICS IN INSECT CONTROL

ORGANIZER: M.J. WHITTEN

WHO/ICMR PROGRAMME OF GENETIC CONTROL OF MOSQUITOS IN INDIA

R. Pal and G.C. La Brecque

Vector Biology and Control Unit, W.H.O., Geneva, Switzerland

The WHO/ICMR Research Unit on the Genetic Control of Mosquitos was established late in 1969 to determine the operational feasibility of genetic control techniques for the control or eradication of *Culex fatigans* and to obtain data on the reproductive biology and population dynamics of *Aedes aegypti* required for genetic control of this species.

The procedure and techniques for mass rearing and sterilization of *Culex fatigans* have been developed. Sterilization by either radiation or chemicals produces no adverse effect on longevity and mating competitiveness of the males. Field releases of males sterilized by either method have indicated that a high degree of sterility can be induced in natural populations. Investigations are also being carried out on a cytoplasmically incompatible strain (D3) of *Culex fatigans* and a strain comprising both incompatibility and translocations (D3/71). Field studies have been initiated to compare the biological effectiveness of all these methods. Ecological studies have been carried out on an estimation of absolute populations, determination of natality, mortality, and net reproductive rate of *Culex fatigans* populations in experimental areas.

Studies with *Aedes aegypti* have demonstrated the introduction of two mutants, a silver thorax marker and a translocation for partial sterility into field populations. A number of translocation homozygote stocks of *Aedes aegypti* have been developed. Further experiments are in progress on homozygotes and the double heterozygotes derived by crossing them, particularly on their biological fitness and potentialities for genetic control.

INHERITED STERILITY FOR CONTROL OF LEPIDOPTEROUS AND HEMIPTEROUS PESTS

D.T. North

Metabolism and Radiation Research Laboratory, ARS, U.S.D.A., Fargo, North Dakota, U.S.A.

The progeny of irradiated or chemically treated Lepidoptera or Hemiptera inherit genetic damage that renders them fully or partially sterile. This has been demonstrated in over a dozen species of Lepidoptera and in at least three species of Hemiptera. The use of inherited sterility to control or suppress natural populations of these insects is promising. The technique is applicable only to species with holokinetic chromosomes, and there is both a species and sex difference in the amount of sterility inherited by the progeny. The major advantages of this approach over releasing fully sterile insects for control are: (1) The released insect is more competitive since it has received less radiation; (2) fewer insects need to be released; and (3) other means of control can be used simultaneously. The progeny from an irradiated lepidopteran male are always more sterile than the male parent. The progeny from irradiated females do not inherit as much sterility as do the progeny from treated males. The amount of sterility inherited in progeny of treated Hemiptera, regardless of the sex treated, is usually not as great as in Lepidoptera. Data on the effectiveness of this technique will be presented from laboratory, field cage, and field studies. For some species, particularly where the sterile male is not competitive, this technique affords a highly efficient means of genetic control. Various means of utilizing inherited sterility will be discussed and a brief summary of its genetic nature will be given.

THE DEVELOPMENT OF GENETIC METHODS OF CONTROLLING THE SHEEP BLOWFLY, *LUCILIA CUPRINA*

G.G. Foster

Division of Entomology, CSIRO, Canberra, A.C.T., Australia

The blowfly genetics section of the Division of Entomology, CSIRO, is using genetic techniques to develop strains of *Lucilia cuprina* suitable for use in long-term low-cost control of this pest. One approach envisages the introduction of a self-perpetuating genetic load into a pest population through the release of strains homozygous for two or more viable translocations. A second approach under consideration involves the use of special translocations such as compound chromosomes as transport mechanisms to effect replacement of a native pest population by a conditionally lethal strain, such as one unable to survive winter temperatures. The methods used and the progress to date in the isolation of translocations and conditional lethal mutations are reviewed. The relevance of these approaches to genetic control of other higher Diptera is discussed.

PRODUCTION OF CHROMOSOME MUTATION STRAINS OF *TETRANYCHUS URTICAE* KOCH FOR GENETIC CONTROL PURPOSES

W.P.J. Overmeer

Laboratory of Applied Entomology, University of Amsterdam, The Netherlands

It was investigated whether spider mite strains (*Tetranychus urticae* Koch) could be developed which are reproductively incompatible with the strain they are originally derived from due to chromosome mutations induced by X-irradiation.

Establishment of complete reproductive incompatibility between strains would mean an important step forward with respect to a possible application of genetical methods for spider mite control.

Chromosome mutations were induced in the sperm by X-irradiating spider mite males at 2200 r. By following a particular crossing scheme, a number of viable chromosome mutation homozygote strains were obtained. These strains showed high degrees of reproductive incompatibility towards each other. A strain homozygous for two separately induced chromosome mutations appeared nearly completely incompatible with the other chromosome mutation strains, in the sense that over 99% mortality in the haploid F_2 was found, while the F_1 of the various combinations was viable.

GENETIC RESISTANCE IN RICE PLANTS TO PEST INFESTATIONS

M.D. Pathak

The International Rice Research Institute, Los Baños, Laguna, The Philippines

From a total of 10,000 rice varieties tested, 20 were recorded as resistant to the striped borer. Also, several varieties have been identified as resistant to the green leafhopper, the brown planthopper, the white-backed planthopper, and the rice whorl maggot. The genetics and the causes of resistance are being investigated. Under field conditions, the resistant varieties develop only small infestations even when susceptible varieties planted in adjacent plots are killed.

The variety IR20, developed by crossing TKM 6 (resistant to striped borer) with $Peta_3$ x Taichung Native 1 (improved plant type), is resistant to the striped rice borer, the green leafhopper, the tungro virus, the bacterial leaf blight, the bacterial leaf streak and the rice blast. Furthermore, it has high yield potentials and fine grains. At present, it is the most widely cultivated improved rice variety in the Philippines, Bangla Desh and Vietnam. Intercrossing of the green leafhopper and the brown planthopper resistant varieties have produced progenies that are of improved plant type and are highly resistant to both these insects.

SYMPOSIUM NO. 4

INSECTICIDE RESISTANCE

ORGANIZER: R.W. KERR

STATUS AND CONSEQUENCES OF RESISTANCE

A.W.A. Brown

Vector Biology and Control, World Health Organization, Geneva, Switzerland

Since the last Congress, the number of species recorded as having developed resistance has increased by about 10% to about 250. The new records concern mainly dieldrin-resistance in root maggots, root grubs, cotton insects and *Rhodnius*, and organophosphorus-resistance in mites, leafhoppers, mealy-bugs, scales and body lice. Standard resistance tests are now available for many crop arthropods and stored products insects, and most pests of man.

The main consequence of resistance has been to accelerate the substitution of organochlorine by organophosphorus and carbamate insecticides. Serious situations exist where the pest has developed resistance to these OP or cambamate substitutes, such as the cotton leafworm in Egypt, rice leafhoppers in Japan, cattle tick in Queensland and encephalitis mosquitos in California. Stress is being placed on supplementing chemical with biological control, and thus insecticide-susceptibility levels of predators and parasites become important.

The lack of new chemical groups of insecticides, the cross-resistance spectrum of problem pests, biodegradable analogues of DDT, and juvenile-hormone analogues are matters needing further examination. Systematic surveillance of resistance and cross-resistance levels remains the best means of coping with the problem.

THE IMPACT OF INSECTICIDE RESISTANCE ON BASIC AND APPLIED SCIENCE

J.R. Busvine

London School of Hygiene and Tropical Medicine, London, England

Insecticide resistance forced itself on human attention through the entirely practical circumstance of failures in pest control. The first attempts to cope with it were empirical and were not only useless but exacerbated the problem. Gradually, more and more scientists turned their attention to the fundamental causes and a substantial amount of fine basic research has resulted. Apart from its practical implications, the subject involves interesting aspects of many scientific disciplines.

GENE REGULATION IN HIGHER ORGANISMS AND ITS RELATION TO THE DEVELOPMENT OF BIOLOGICAL INSECTICIDES

J.A. Thomson

Genetics Department, University of Melbourne, Parkville, Vic., Australia

Intense concentration on studies of the time and mode of action of the moulting (MH) and juvenile (JH) hormones and their analogues has characterized the search for biological insecticides to the present time. The evolutionary age of these hormones in the arthropods, the widespread occurrence of their analogues in plants, and the ability of many insects to detoxify large amounts at most of their life stages, suggest that resistance to analogues of MH and JH is likely to develop even where sensitivity is initially observed. Further, the specificity of such toxic effects may also be generally low. MH and JH may well control "coarse" switching operations triggering preprogrammed developmental sequences in moulting and metamorphosis. The steps within these sequences might be expected to involve evolutionarily more recent, and more species-specific, regulators of gene activity. It is argued that our investment in the search for biological insecticides should therefore include much greater emphasis on the identification of gene regulators (and their competitors and inhibitors) controlling those essential but less general cellular processes which are most highly divergent amongst the insect groups.

THE POTENTIAL OF GENETICS IN INSECT CONTROL

M.J. Whitten

Division of Entomology, CSIRO, Canberra, A.C.T., Australia

Until recently the science of genetics has not contributed to the development of the theory and practice of pest control. While little has yet been transcribed into practice, the ways in which genetics may have a significant impact in this field are beginning to emerge. In some instances it may function to enhance other systems of pest control. Examples of such an auxiliary role include formulation of strategies in biological control, the development of biological insecticides and means for extending the useful life of insecticides.

The most outstanding potential of genetics relates to the development of autocidal systems of pest control. Here the pest species is used in either of two ways. Strains are released which induce, in some manner, sufficient genetic death to cause population decline or else permit the transport and fixation, in natural populations, of genetic traits which are conditionally lethal or remove the obnoxious properties of the pest.

Aspects of the principles of genetic control and some of the current programmes in this field are reviewed.

DETOXICATION MECHANISMS

J.N. Smith

Biochemistry Department, Victoria University of Wellington, New Zealand

Some types of insecticide resistance can be attributed to the action of detoxication enzymes which enable the resistant insects to metabolize insecticides more rapidly than susceptible strains. These detoxications may include oxidations, hydrolysis or conjugations and probably any of these reactions may be emphasised in resistant strains. Examination of the enzymes in normal insects and their inhibition may be of use in countering resistance when this subsequently occurs. Examples will be given primarily from oxidation enzymes and from enzymes dependent on glutathione which detoxify organochlorine and organophosphate insecticides.

FACTORS CONTROLLING THE PROCESS OF POISONING BY TOPICALLY-APPLIED NEUROTOXIC INSECTICIDES

P.E. Burt

Rothamsted Experimental Station, Harpenden, Herts., England

The mechanism of the poisoning process initiated by topical application to insects of lethal doses of neurotoxic insecticides is discussed. Possible routes to the sites of action are described and their relative importance compared in the light of the experimental evidence. The extent to which the distribution of the insecticide within the insect can help to identify the critical sites of action and the processes where resistance is mainly expressed is considered.

DESIGN OF NEW INSECTICIDES AND THE MODE OF ACTION OF DDT

G. Holan

Division of Applied Chemistry, CSIRO, Melbourne, Vic., Australia

A steric model of hydrocarbon insecticides which includes the structure of DDT was used to establish a theory of their mode of action. This theory is supported by neurophysiological and other biological studies.

The general steric model was further used for the predictive synthesis of new series of broad spectrum, degradable insecticides which possess low mammalian toxicity.

The implications of this work on insect resistance, mammalian toxicity and persistence of the hydrocarbon insecticides in the environment will be discussed.

THE FUTURE ROLE OF CHEMICALS IN INSECT CONTROL

R. Gasser

CIBA-GEIGY, Ag.Chem. Div. Res. Dept., Basle, Switzerland

Despite the success achieved by biological pest control methods, such as physical control, the use of natural enemies and pathogens, the release of sterile individuals and the potential for control by inducing genetic changes in insect populations; and also in spite of the negative aspects of chemical control, such as mammalian toxicity, residues and environmental pollution and their general disturbance of the biological equilibrium; chemical pesticides seem likely to play just as important a role in the foreseeable future, in defending man against disease vectors and pests which attack his plant and animal foods, as they have in the past 30 years.

But the properties demanded of new chemicals will in future be as much influenced by environmental considerations as by their mode of action, spectrum of activity and improved methods of application.

SYMPOSIUM NO. 5

REGULATION OF INSECT DEVELOPMENT

ORGANIZER: D. GILMOUR

JUVENILE HORMONE: IN RETROSPECT AND IN PROSPECT

Carroll M. Williams

Biological Laboratories, Harvard University, Cambridge, Mass., U.S.A.

The lecture will report on scientific studies which have paved the way for the selective control of insects by synthetic analogues of juvenile hormone - the so-called "third generation pesticides." Attention will be focused on recent *in vivo* and *in vitro* studies which have led to a comprehensive theory of the mode of action of juvenile hormone and analogues thereof.

ROLES OF THE FAT BODY IN REGULATION AND METAMORPHOSIS

G.R. Wyatt

Department of Biology, Yale University, New Haven, Connecticut, U.S.A.

The fat body is a tissue unique in the many roles that it plays in insect physiology and development. As the chief source of the organic components of the haemolymph, it is important in homeostasis; as chief site of storage of lipids, carbohydrate and protein, it is essential for metamorphosis. Regulation of haemolymph trehalose levels is achieved by feedback inhibition of the synthetase in the fat body by trehalose. In the cecropia silkmoth, blood sugar is maintained at a different level in each developmental stage, and one element in modulation of the control system is changing permeability of the fat body cells to trehalose. As a reserve during metamorphosis, the fat body lays down protein storage granules, which have been known microscopically for many years. These have now been isolated from cecropia pupal fat body, shown to be partially crystalline, and their biochemistry is being studied.

ENDOCRINE CONTROL OF OOGENESIS IN *RHODNIUS PROLIXUS*

K.G. Davey

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Oogenesis in *Rhodnius* is governed by a complex of hormones. Allatectomy results both in a depression of the level of specific yolk protein and a failure of the follicle cells to become patent and allow the yolk protein access to the oocyte surface. This reduces, but does not abolish, egg production. The neurosecretory cells of the pars intercerebralis are essential to the increase in egg production which follows mating. The evidence suggests that the hormone involved is a myotropin. In virgin females the myotropin is not released, ovulation does not take place, and mature eggs accumulate in the ovary. Evidence will be presented which demonstrates that ovaries containing mature eggs (as in virgin females) release a new hormone, an antigonadotropin, which blocks the action on the follicle cells of the gonadotropin from the corpus allatum.

THE ECDYSONES: BIOCHEMISTRY AND MODE OF ACTION

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Alpha-Ecdysone was first isolated in 1953 by Karlson and Butenandt, as the first insect hormone obtained in crystalline form. It is a steroid hormone with a number of hydroxyl substitutions. Shortly afterwards, the occurrence of another factor, beta-ecdysone, was demonstrated. This compound was later reisolated as "crustecdysone", "ecdysterone". Moreover, many compounds isolated from plants and structrally related to ecdysone are active in bioassays.

The biochemistry, i.e. the route of biosynthesis and inactivations will be reviewed. One of the inactivation products has recently been identified in our laboratory.

Interest in the mechanism of action arose mostly from the finding of Karlson and Clever (1960) that ecdysone can induce puffing in salivary gland chromosomes. Since that time, the action of ecdysone on RNA and proteinsynthesis has been in the center of interest. This field will be reviewed with special emphasis on the action of ecdysone on isolated nuclei of several tissues.

THE ROLE OF PROTEIN SYNTHESIS IN HOLOMETABOLOUS METAMORPHOSIS

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The processes involved in the utilisation of nutrient reserves and the formation of the characteristic proteins of the adult have been under investigation for some years, especially with a number of dipterans. Evidence will be presented for the existence of a proteolytic capacity in the pharate adults of the blowfly *Lucilia* adequate for the provision of the amounts of amino acid necessary for adult development and for the dependence of this development on *de novo* synthesis of both individual proteins (cytochrome c and the α glycerophosphate dehydrogenase of the cytosol) and the bulk protein of the insect. The significance of this work will be discussed in relation to other published results on dipteran metamorphosis and the data available from studies with other types of insects.

MECHANISM OF PUPARIUM FORMATION IN FLIES AND ITS HORMONAL CONTROL

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Puparium formation (pupariation) in flies consists of a sequence of several distinct morphogenetic processes which normally occur in the following order: Retraction of anterior end, muscular contraction, longitudinal cuticular shrinkage, stabilization, and tanning. These are not chain reactions. Injection of hormones or drugs can suppress some of these events, or make them occur out of sequence. Pupariation is greatly accelerated by the injection of CNS-homogenates, or of hemolymph from pupariating larvae. The accelerating substances, provisionally termed X-factors, are of the nature of proteins, with m.w.'s of 50 to 100,000. Two distinct factors can be discerned: X_r which acts predominantly on anterior retraction, and X_t which accelerates contraction/shrinkage and tanning. The activity in the CNS is predominantly X_t and that in the hemolymph X_r in nature. These observations fit a scheme whereby ecdysone causes the appearance and/or accumulation of the X-factors in some tissue, and their ultimate release into the hemolymph where they induce pupariation. A product of neurosecretion in the CNS accelerates this release. An alternative explanation assumes that the X-factors originate as a neurosecretion which is stored in the peripheral axons or synapses prior to their release into the hemolymph by the action of ecdysone. Either scheme postulates the existence of two proteinaceous substances, most probably of the nature of hormones, interposed between ecdysone and its visible effects in puparium formation.

SYMPOSIUM NO. 6

INTERACTIONS BETWEEN ARTHROPODS AND THEIR HOSTS

ORGANIZER: R.M.M. TRAYNIER

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HOST FINDING; ESPECIALLY BY CERTAIN SCOLYTIDAE

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Host finding by scolytids may involve plants ranging from obviously healthy to dead. The relative role of chemical messengers among the total stimuli associated with the host which may guide scolytids to the host usually increases as the host declines from a state of vigorous health. Pheromones have been implicated as important stimuli to aggregate populations of scolytids on their hosts. In some cases, single chemicals seem to be the pheromone, while in other scolytids a mixture of pheromones, or pheromones and host-derived chemicals, is essential for maximum response under field conditions. In order for a scolytid to respond significantly in any aspect of its host finding behavior, a threshold temperature must exist, and other physical factors such as light and wind direction and speed may be limiting. The physical factor of host density also can be important.

SOME INFLUENCES OF PLANT CHEMICALS ON INSECT BEHAVIOUR

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Mustard-oils of Cruciferae attracted adults and newly hatched larvae of the vegetable weevil (*Listeroderes obliquus*), a polyphagous insect attacking over 150 species of 30 plant families. Mustard-oils also stimulated biting in adult weevils. In addition, adult *L. obliquus* were attracted to sweet clover leaves but did not eat them. Coumarin, a characteristic odour substance of sweet clover leaves, attracted adults but inhibited their biting and feeding. Females of the onion maggot (*Hylemya antiqua*) were both attracted and stimulated to oviposit by the volatiles of onion, n-$(C_3H_7S)_2$ and n-C_3H_7SH. The willow blue leaf beetle (*Plagiodera versicolora distincta*), which normally feeds on willow or poplar leaves, was stimulated to feed by salicin, a glucoside of Salicaceae, but only in the presence of sucrose. These results illustrate the complexity of the effects of plant chemicals on insect behaviour, and especially the dual influence of some substances.

CHEMICAL WARFARE BETWEEN PLANTS AND INSECTS

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"Secondary plant-substances" probably evolved as specific deterrents to phytophagous animals, and it is assumed that some insects became first tolerant and then attracted to these substances. Plants possess in addition a more general protective mechanism, however: wounding triggers a phenol-phenolase system that produces toxic intermediates and finally seals off the damaged cells. Two kinds of organism that are liable to assimilate or be otherwise exposed to the products of damaged plant cells have apparently evolved non-specific detoxifying systems; both plant-bugs and phytopathogenic fungi introduce into plant cells their own phenolase, which can be presumed to speed the oxidation of the plant toxins to non-toxic endproducts. The salivary phenolase system in Hemiptera may also explain *inter alia* the development of biotypes able to attack so called resistant varieties of plants.

INFLUENCES OF PLANTS ON APHIDS

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Many attributes of plants influence the behavior and physiology of aphids and hence affect the distribution and population build-up of these phytophagous insects in nature. The responses of aphids to a number of these attributes have been studied in detail in recent years, and the literature will be reviewed to illustrate how some of the strong ecological associations that exist between aphids and their host plants may come about.

INTERACTIONS BETWEEN BITING FLIES AND THEIR HOSTS

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Known interactions between blood-sucking flies and both their plant and their animal hosts are reviewed and classified. Selected examples of some of the less well-known kinds of interaction are discussed in more detail, and special attention is given to thermal and to a lesser extent microchemical interactions. Some aspects of the origins and phylogeny of the Diptera are discussed in relation to the evolution of interactions both with plants and with animals. The more conspicuous morphological differences between the main groups of blood-sucking flies are also referred to in relation to their host-interactions.

BEHAVIORAL ASPECTS OF CHEMORECEPTION IN BLOOD-SUCKING ARTHROPODS

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Haematophagous arthropods which obtain their blood meal from warm-blooded animals, orient themselves to the host along a temperature gradient in the vicinity of the host. Host temperature induces also probing and tasting of the blood. However, to switch from tasting to gorging, a chemical cue from the food is necessary. Special "blood receptors", situated either on the mouthparts or in the buccal cavity, have to come in contact with these chemicals to elicit this feeding process. It was found that the gorging factor for blood-sucking insects is adenosine triphosphate (ATP). All adenine nucleotides show some stimulatory activity, while other nucleotides are ineffective for haematophagous Diptera and fleas, but show some activity for *Rhodnius* and ticks.

About 99% of the blood ATP are confined to the red blood cells, and are not available to the insects' chemoreceptors. The blood platelets alone elicit feeding by releasing their nucleotide content. Ticks, although stimulated to a certain extent by ATP and some other nucleotides - in the presence of glucose - show full gorging response to reduced glutathione and to some amino acids. This effect is synergized by glucose. Thus, the range of stimuli narrows with the evolution of the groups - being quite wide in ticks, and limited to ATP alone in fleas.

INTERACTIONS BETWEEN TICKS AND THEIR HOSTS

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Hosts represent environments to long-feeding Ixodidae as well as nutrient sources. These environments vary from host to host (individuals and species) and change during single tick attachments and following previous infestations. Host environments may be physically deleterious unless successful tick attachment occurs. Skin environments below tick mouthparts change by salivary action and host responses. The latter cause tissue destruction and ticks may move to fresh sites within an instar. Many hosts acquire resistance; attaching and maturing tick numbers and blood meal sizes decrease. Rapidly feeding Argasidae may be less affected during feeding but previously infested hosts may be less attractive and their blood toxic to ticks. Ticks and hosts interact in nature to develop equilibria controlling potentially vast tick numbers by many checks. Man frequently destroys these stable situations.

INTERACTIONS BETWEEN FLEAS AND THEIR HOSTS

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The mammalian hormones control reproduction of *Spilopsyllus cuniculi* (Dale) and thus the breeding cycles of flea and rabbit are synchronized. In the spring (April and May) while feeding on the pregnant doe and nestlings, maturation of both sexes of the flea is accelerated. Egg-laying on the newborn young at this time occurs within 24 instead of 48 hours following the experimental transfer of fleas from the oestrus doe to the nestlings, and copulation takes place about 5 hours earlier.

Males and females of *Nosopsyllus fasciatus* Bosc. reared on mice emerge from the pupae with blocked testis, empty epididymis and undeveloped ovaries. They require a blood meal before pairing occurs. Reared on rats (the normal host) the females at eclosion have yolk-laden oocytes and the male testis are open and the epididymis full of sperm. They are able to copulate and the female is impregnated before either sex has partaken of a blood meal.

THE CHEMICAL BASIS OF RELATIONSHIPS BETWEEN PARASITOIDS AND THEIR HOSTS

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Host location by two species of braconid and a species of ichneumonid parasitoids of the *Heliothis* complex (Lepidoptera: Noctuidae) is accomplished by their oriented searching response to a chemical left on the substratum by the host. Host acceptance and oviposition are dependent on the presence of this host chemical and other factors associated with the cuticle. During oviposition a host marking pheromone which inhibits further host acceptance is deposited on the host by the parasitoid. The alkaline gland is the source of the host marking pheromone in the three species of parasitoids investigated. In addition, the ichneumonid parasitoid injects a material into the host during oviposition. This material inhibits oviposition by subsequent females of the same species. The source of the internal ovipositional deterrent is the lateral oviducts of the female parasitoid.

The lateral oviducts of several species of parasitoids also produce protenious materials that regulate host growth and development.

SEASONAL SYNCHRONIZATION OF HOST-PARASITE DEVELOPMENT

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Seasonal host-parasite synchronization of development is obligatory condition of existence of parasitic species. The development of the parasite is always influenced by the host as a source of food. But the host is not always a factor controlling seasonal development of a parasite.

At least three different mechanisms are known to control the synchronization of seasonal development of parasitic insects and hosts:

1. Correspondence of seasonal development can be reached by completely independent but analogous reactions on the influence of ecological conditions. This group of parasitic insects has the ability to synchronize their seasonal development with seasonal rhythms of climate.
2. Seasonal synchronization of the other parasitic insects is reached by influence of both ecological conditions and host physiology. This mechanism of synchronization of seasonal development seems to be widespread among parasitic insects.
3. In many cases there is complete dependence of the parasite on the host. But even parasitic insects of this group are capable of some self-regulation during the endoparasitic stages of their ontogenesis.

SYMPOSIUM NO. 7

EXPERIMENTAL ANALYSIS OF INSECT BEHAVIOUR

ORGANIZER: L.B. BARTON BROWNE

CHANGES OF RESPONSIVENESS IN THE PATTERNING OF BEHAVIOURAL SEQUENCES

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The successful demonstration of central patterning in insect behaviour began with single rhythmic activities in which the motor sequence is simple and repetitive and thus readily identifiable in "marker" patterns to look for centrally when we wish to go further and examine the central contribution to the co-ordination of different types of motor activity, as they succeed one another at varying intensity to make up behavioural sequences. A new requirement now arises, for prior identification of regular features in the behaviour itself that are likely to be central in origin. To be adaptive, such sequences must be highly stimulus-dependent but include a central contribution in the form of appropriate changes in responsiveness as the stimulus-response sequence proceeds. The aim of the aphid experiments to be described has therefore been to identify regularities in such changes of responsiveness.

An earlier study of the interaction between two mutually exclusive behaviours, flight and settling, showed that responsiveness can be both increased and decreased by temporary inhibition during elicitation of an antagonistic response, indicated the conditiions governing which of these after-effects of inhibition would predominate, and located the inferred interaction on the afferent rather than the efferent side of the CNS. The generality of these findings remained in doubt since so much of behaviour is made up of response s that are not outright antagonists but are in some degree allied. However, subsequent experiments on two partially allied behaviours, flight toward a light and flight toward a landing target, have given similar results, and shown in addition that the positive effect of inhibition occurs even while it is being imposed and not only as an after-effect or "rebound".

SENSORY INPUT AND THE INCONSTANT FLY

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Specific behavioural responses are by no means invariant. The unpredictability of behaviour indicates that the organism is not the same from one moment to the next. It is generally assumed that response variability reflects either a change in internal states brought about by antecedent events or the expression of an oscillating endogenous system. It is further assumed that sense organs whose actions contribute to behaviour transmit reliably and accurately every time an adequate stimulus is presented. Electrophysiological analyses indicate that this may not always be the case. While some of the variability in response is traceable to recording artefacts, it is clear that there is some inherent instability in receptors.

SENSORY PHYSIOLOGY IN THE CENTRAL NERVOUS SYSTEM OF INSECTS, AND ITS RELATION TO BEHAVIOUR

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This paper considers the major functional uses of sensory input, as grouped by the effect on behaviour. Detection of an orientation to environmental stimuli are classical functions. The regulation of motor output is a very diverse function, especially when both centrally programmed repetitive motor patterns and others of a more reflexive nature are both considered. In addition, sensory input activates neuroendocrine systems and contributes to arousal, attention and selective perception. The contribution of electrophysiological studies in the CNS to an understanding of these functions is considered.

THE ANALYSIS OF SOME FORMS OF RHYTHMICAL BEHAVIOUR

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Some types of activity in insects comprise the regular repetition of a movement or series of movements. More complex behaviour may involve a sequence of activities regularly repeated. In some cases the omission of one act does not impair the performance of the remainder, but in others the execution of an act is a prerequisite for the appearance of the next. Such interaction may take place centrally to be dependent on sensory input.

Single neurones can act as oscillators producing trains of evenly spaced impulses, or bursts of impulses, or slow oscillations of potential without impulses. Pacemakers of these types may act in pattern generation and underlie several types of behaviour. They are believed to be important in breathing movements. Groups of spontaneously active neurones may interact to produce complex patterns. Neurones which identify spatially or temporarily patterned inputs are little understood but may depend on similar principles: species isolating mechanisms require them to be precise.

Coordinating interneurones distribute activity from pacemakers directly or indirectly to motor neurones. Segmental ganglia may be activated serially to produce a metachronal movement or nearly simultaneously to produce a synchronised movement. Both systems can be recognised in insect ventilation, and in some species they may exist in parallel.

ROLE OF HORMONES IN THE CONTROL OF INSECT BEHAVIOUR

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Hormones may serve as either releasers or primers of insect behaviour. As a releaser, the hormone triggers a specific behavioural sequence; the few known examples will be briefly considered. The more widespread primer action is manifest in a hormonally-induced alteration of the nervous system so that stimuli evoke new or different responses. In some instances, hormones may permanently switch on a new mode of behaviour which then persists in the absence of the hormone. More commonly, the maintenance of the new behavioural mode requires the contemporaneous presence of the hormone. If the hormone is withdrawn or antagonized by other agents, then the behavioural response disappears. Experimental analysis of the primer function of hormones will be discussed.

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SYMPOSIUM NO. 8

PHEROMONES

ORGANIZER: R.J. BARTELL

PHEROMONE-MEDIATED BEHAVIOUR

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There are many possible methods for classifying responses of insects to pheromones. The most commonly used method is based on the biological function served by the response to the pheromone. This gives rise to such terms as "sex pheromone", "alarm pheromone", "aggregation pheromone", and "trail pheromone". The behaviourist analyzes responses at a different integrative level. He finds that many of the behavioural mechanisms that bring about the responses may be identical for several of the above functional categories. Thus, a sex pheromone may cause a male moth to arrive at the vicinity of a female, and an aggregation pheromone may cause a female beetle to arrive at the vicinity of another female that has located a suitable food source. However, in either case the behavioural responses to the pheromone may involve locomotory activation, positive anemotaxis, cessation of locomotion at high chemical concentrations, and sensitization to certain visual stimuli.

A NEW LOOK AT HOMING AND RECRUITMENT IN ANTS

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Investigations on ants have shown that trail pheromones are used as recruitment signals and as specific homing cues. During homing the harvester ant *Pogonomyrmex badius* orients both to the sun and to chemical cues. Visual patterns (generally less important) may be used with chemical signals to locate the nest entrance. At least two chemical releasers seem to be important during foraging: a short lived recruitment signal from the poison gland, and a long lived orientation cue from the dufour's gland. These pheromones are important in establishing spacing patterns of nests.

Scout ants of *Camponotus socius* set chemical 'signposts' (hind-gut material) around newly discovered food sources or new nest sites. (This has no recruitment effect.) Inside the nest the recruiting ant performs a 'waggle' motor display which causes nest mates to follow. Only those ants which are stimulated by the 'waggle' display will follow the hindgut trail and the presence of the recruiting ant is required to keep the followers excited.

AGGREGATION PHEROMONES AND THEIR ROLE IN THE CHEMICAL ECOLOGY OF BARK BEETLES

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The mass attack and colonization of certain trees by bark beetles is guided by a complex of chemical compounds emanating from the beetles and their host trees. Pheromones present in the beetle hindguts can be detected and isolated by gas chromatography. Comparative studies on *Dendroctonus* species show that most pheromones are common to several species and may be produced by either sex, but specificity exists in the function of these compounds. Similarly, a limited number of pheromones is shared by several North American and European *Ips* species. Cross attraction occurs in many cases, but subtle chemical differences are instrumental in the maintenance of species integrity. Prey perception by insect predators and the effect of host tree condition on the mechanism of colonization by bark beetles are among other ecological factors which can be explained on a chemical basis.

A BARK BEETLE PHEROMONE RESEARCH PROGRAMME

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In recent years much information has been obtained regarding behavioral and chemical aspects of the pheromone communication system of *Dendroctonus brevicomis*, an economically important bark beetle occurring in western North America. Knowledge of this communication system, which enables beetles to aggregate in sufficient numbers to successfully attack and kill trees, has advanced to the extent that several synergistic pheromones have been identified and synthesized. Finding ways to utilize these pheromones to manipulate beetle behavior to human advantage is a challenging problem which currently is being studied cooperatively by scientists at the Department of Entromology and Parasitology, University of California, Berkeley, and the United States Forest Service. Entomologists, foresters, chemists, and systems analysts from these organizations are coordinating research efforts in order to conduct extensive field tests with pheromone-baited traps and to evaluate the impact of trapping on the population dynamics of the beetle and some of its natural enemies.

PHEROMONE RECEPTORS

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Morphological features of insect olfactory organs are discussed in regard to their role in stimulus conduction from the site of molecule impact to the transduction site at the dendrite membrane. Within one sensillum there can be olfactory cells specialized for one particular releaser pheromone together with cells which respond to a variety of odors. Insect pheromones chiefly act by depolarizing the dendrite membrane so giving rise to nerve impulses but there are examples of hyperpolarization and blocking of nerve impulses by pheromones. There is evidence that single molecules of the female sex lure elicit single nerve impulses in receptor cells of male moths. From the response spectra of single cells to stepwise altered molecules, structure-activity relations will be discussed in terms of binding to olfactory acceptors. In view of the lack of species specificity of many pheromones it has been surprising to discover that pheromone acceptors were found to react differently even between closely related species.

MODULATING SEX ATTRACTANCY IN LEPIDOPTERA

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Sex attractants for over 100 species of Lepidoptera have been defined by various methods - classical rigorous characterization, electroantennogram technique and/or field screening of various standards. The known attractant structures are mostly straight chain acetates and alcohols, although attractant structures have not been identified for several major families. Since many species evidently utilize the same compound in their attractant communication system, it is important to determine the factors operating as isolating mechanisms in the field. A study of the effects of other related chemicals suggests that secondary attractant chemicals can play an important role in increasing the potency of the attractant for one set of males, while decreasing attractiveness for males of another species that utilizes the same main attractant.

The use of attractant blends, inhibitors, rate of release, etc., appear to play a role in reproductive isolation, in addition to the more commonly known methods of differences in seasonal cycles, habitats and circadian rhythms of activity.

BIOLOGICAL ACTIVITIES OF INSECT SEX PHEROMONES AND PARAPHEROMONES

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Chemicals that possess pheromonal activity, but that are not identical in structure to the natural pheromone of a particular species (termed "parapheromones" = pheromone-like substances) have received considerable study. Particular attention has been directed towards a quantitative determination of the biological activity of sex pheromones and parapheromones of *Bombyx mori*, *Pectinophora gossypiella* and *Trichoplusia ni* (Lepidoptera).

Forty monounsaturated straight-chain alcohols and derivatives, structurally similar to the *T. ni* sex pheromone, *cis*-7-dodecenyl acetate, were synthesized in high purity and tested behaviorally. Field and laboratory bioassays were performed to determine which structural features have the most effect on biological activity. Some compounds were completely inactive, but 14 compounds showed an activity spectrum from at least equal to natural sex pheromone down to one millionth of the activity.

The use of parapheromones as possible tools for mechanistic studies on interactions between pheromone and receptor cell as well as for insect control is discussed.

PHEROMONES: PROSPECTS FOR CONTROL

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Although pheromones are being used extensively for surveying and monitoring insect populations, increasing attention is being focused on their use for control. Research on the use of pheromones as direct control measures can be roughly divided into two areas; disruption and mass trapping.

Prospects for using one or the other of these control techniques remain bright despite many physical and legal problems. In the disruption approach, these problems can be related to two important factors. One of them is the dispensing system for the pheromone; or more specifically, the formulation. The other is meeting the requirements of registration. In most countries, attractants used in insect control are defined as pesticides or economic poisons.

A problem associated with mass trapping programs is the development of a wick which is more efficient than a virgin female. Another problem is one of economics, in that large numbers of traps are required to successfully exclude the insect. Programs utilizing these two techniques are currently under way with various degrees of success reported. Where possible, results will be discussed.

SYMPOSIUM NO. 9

QUANTITATIVE EVALUATION OF NATURAL ENEMY EFFECTIVENESS

ORGANIZER: R.D. HUGHES

INTRODUCTORY REVIEW OF THE NEED FOR EVALUATION STUDIES IN RELATION TO INTEGRATED CONTROL

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The activity of biotic antagonists (predators, parasites and pathogens as well as genetically inferior individuals of the same species) plays a particular rôle among all mortality factors that can be manipulated for an integrated control programme. Their special quality is defined and a few historical examples are given to show the beginning of this approach a century ago. The importance of a correct prognosis for integrated control is stressed. This should include an understanding of the potential effects of any epizootics.

The quantification of the efficiency of natural enemies and its correct prognosis allows the grower to adjust other control measures to the economically defined goal: To keep the pest population below the "economic injury threshold". For all transpositions between natural enemy activity - level of pest population - economic losses in comparison with expenses for control operations - all these calculations are made comparable by use of a common denominator: *money*. The problem will be discussed whether the need for an assessment of natural enemy efficiency will be influenced by the fact that two fields of insect pest control go beyond the approach of the "economic injury threshold": (a) the control of vectors of human diseases (because the lives saved cannot be calculated in monetary entities), and (b) the plant pest control in landscapes of no commercial, but important social and/or hygienic value; examples are recreation areas or oxygen producing and water preserving forests. The hypothesis will be presented that particularly in cases of type (b) the utilization of natural enemies becomes a mandatory part of plant protection. Therefore, the future need for evaluation of natural enemy efficiency will be increasing, particularly in areas of crowded human populations.

DIFFERENT APPROACHES TO THE QUANTITATIVE EVALUATION OF NATURAL ENEMIES

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The advantages and disadvantages of the various methods which have been used to assess the importance of natural enemies are discussed.

Indirect, correlative methods have been used by some workers, but these have all of the disadvantages associated with correlation; in particular the difficulty of identifying causative relationships.

Direct methods of studying natural enemies may be divided broadly into four: (a) exclusion or removal techniques; (b) feeding - trace techniques; (c) the direct-count-method; and (d) experimental assessment.

The experimental nature of exclusion or removal techniques has some advantages in demonstrating the effectiveness of natural enemies. Techniques involving the use of cages, or insecticides, to remove enemies may, however, have uncontrollable side-effects on the prey. Hand-removal of arthropod predators is extremely time consuming and is unlikely to be completely successful.

Feeding trace techniques (e.g., serology, radioactive labelling, paper chromatography, etc.) all have the disadvantages of having to remove enemies for testing, thus altering the field situation. These techniques provide a means of studying concealed or nocturnal species, which cannot be directly observed. Of these, serological techniques are probably the most useful for studying arthropod predators.

The direct-count method has the advantage that natural enemies do not have to be removed. It also makes possible the study of cannibalism, carrion feeding and alternative prey species. On the other hand, its use is restricted to those enemies whose activity is directly observable.

The application of the results from the experimental assessment of the effect of a natural enemy in the laboratory to field conditions is usually difficult. For this reason, the value of this approach is limited to extremely simple situations.

Some relevant examples of field trials conducted by the authors are presented and the effectiveness of natural enemies in controlling pests is discussed briefly.

GENERAL APPLICABILITY OF EVALUATION RESULTS

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Rational pest control should entail the quantitative evaluation of natural enemy effectiveness. Choice of evaluation method and the applicability of the results obtained depend on the specific nature of the problem or the requirements of the investigator.

Exclusion methods provide fast and reasonably accurate information on the relative contribution of single mortality factors. Results are applicable only to the situation investigated or to essentially identical situations.

Life-table studies are time consuming and laborious. They provide information on the relative contributions of all recognizable mortality factors. The predictive power of life-tables with regard to population regulation is limited.

Complex mathematical models (homomorphs) of real-life systems which have been constructed from the measured functional and numerical responses of natural enemies can be used to analyse the effects of governing factors and dependent variable states. Among the more common limitations to the applicability of computer simulation studies are: The model is deterministic and does not sufficiently allow for biological variability. Separable factors are not operationally defined because of inadequate biological knowledge of the interacting system. Alternatively, if variables are operationally defined a linear or curvi-linear relationship is assumed to exist throughout the range of operation and points of inflection are neglected. No provision is made for differences in population structure over a geographical range.

Reference is made to the evaluation of natural enemy impact on aphid populations. Particular problems result from the ephemeral and discontinuous nature of aphid populations, the absence of discrete generations, and the diversity of the interacting parasite and predator complex. It is suggested that existing models for estimating aphid mortalities are not realistic because they do not provide for effects of the host plant and of harvesting and other agro-production practices on aphid and natural enemy populations.

The applicability of population models for the evaluation of alternative parasite strategies is discussed.

THE FUNCTIONAL RESPONSE OF PREDATORS

W.W. Murdoch

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To keep populations of prey insects scarce and stable we need predator populations that can respond so that as prey density increases the predators kill, not only more prey, but an increasing percentage of the prey. Ecologists have recognised two ways that predators can respond: (1) each predator can change its feeding rate (functional response) and (2) they can change in numbers (numerical response). The first is behavioral and has a short time lag; the second is usually thought of as operating with a long time lag.

Although some parasitoids have a stabilizing *functional* response, the most common response found is destabilizing. The number eaten increases with prey density, but does so more and more slowly as satiation is approached, causing a decreasing percent kill. We need the number killed to increase *at an increasing rate* as prey increase.

In spite of this destabilizing response there are other features of predation that can cause such predators to stabilize their prey. This can be illustrated by models and experiments. The destabilizing response is described by a simple model: (1) Under restricted conditions, if we add another prey species to the model we can get one species stabilized without the predator changing its behavior. (2) If the predator becomes conditioned to whichever prey is more abundant when two prey species are present, both prey can be stabilized. If we include responses by the predators in addition to the functional and numerical responses, we can get stability. (3) One such response is variation in growth rate of the predator in response to prey density. (4) Another is an increase in predator efficiency with experience.

This kind of analysis may be becoming developed enough to be of some use in biological control.

THE NUMERICAL RESPONSE OF PREDATORS TO PREY DENSITY

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The effectiveness of predators (or parasites) in controlling insect populations is determined by the total response of the predators to the numbers of prey. The total response is the product of the number of prey killed per predator (the functional response) and the number of predators present (the numerical response) at any given density of prey. These two basic components of predation are usually closely interrelated, the functional response leading to a numerical response at some later point in time.

In assessing a predator's potential for achieving natural control, much importance is often placed on the form of the functional response of the predator to the density of the prey. With insects, and possibly also with many other animals, this emphasis is probably misplaced because it is often the numerical response which causes percentage effect to increase with increasing density of prey.

A numerical response may arise in two different ways. Firstly, there may be a *reproductive response* which is related to the number of prey eaten at some previous time, and secondly, there may be an *aggregative response*, wherein the predators congregate in areas of high prey density and disperse from areas of low prey density.

These two aspects of the numerical response are illustrated by reference to field data concerning predation by ladybird beetles on orchard mites, and by birds on forest-dwelling stick insects.

SYMPOSIUM NO. 10

EVOLUTION IN THE HAWAIIAN DROSOPHILIDAE

ORGANIZER: D.E. HARDY

INTRODUCTION AND BACKGROUND INFORMATION

D.E. Hardy

Department of Entomology, University of Hawaii, Honolulu, Hi., U.S.A.

Drosophilid flies are most remarkably developed in the Hawaiian Islands and represent one of the most unusual faunas of the entire world. We have here a striking example of rapid, adaptive radiation which is almost unparallelled in the animal kingdom and these flies are ideal for evolutionary studies.

Approximately 500 species are now known and we estimate the entire fauna may total 750 or more. This is the greatest known concentration of species in the world; also no other drosophilids are so diverse morphologically and biologically. Our species exhibit a high degree (96+%) of single island endemicity and are unique in many ways from their relatives in other parts of the world. Many strange morphological characters are evident which prove of little or no value in determining relationships. It has become obvious that it is quite impossible to establish phylogenies based upon morphology alone, and relationships have to be determined by pooling knowledge gained by comparative studies of polytene and metaphase chromosomes, hybridization, behavior, ecology, morphology and isozyme variations.

Since 1963 a team research project has been underway using as many approaches as possible to gain knowledge concerning evolutionary processes under insular conditions. This has involved over 20 visiting scientists and about 125 technical assistants and the results of the first 7 years were published in "The Evolutionary Biology of the Hawaiian Drosophilidae" by H.L. Carson, D.E. Hardy, H.T. Spieth and W.S. Stone, 1969, Essays in Evolution and Genetics in honor of Theodosius Dobzhansky, a supplement to Evolutionary Biology Chap. 15: 437-543 (Appleton-Century-Crofts).

ANCIENT CHROMOSOMAL POLYMORPHISM AND ITS USE IN PHYLOGENY

H.L. Carson

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Polymorphism due to the presence of relatively inverted chromosome segments is well-known in existing natural populations, especially in *Drosophila*. Each inversion is monophyletic, arising as a two-break chromosomal mutation; subsequently it may spread through the species population and become a balanced polymorphism. Although most such polymorphisms are unique to the species in which they are found, rare instances are known in which two species display identical polymorphisms. In such cases, the relevant polymorphism is obviously older than the speciation event. Of special interest are those cases in which the "old" and "new" gene arrangements can be distinguished. For example, populations of the Hawaiian *Drosophila* species *D. neopicta* of the Maui island-complex carry a number of polymorphisms. In one of these, the newer of the alternate arrangements is observed to be fixed in all populations of eleven of 16 closely related species. This indicates: (1) that the polymorphism is relatively ancient, pre-dating the formation of the eleven species and (2) that *D. neopicta* may be recognized as having a present-day population in which ancestral genetic properties survive.

DEGREES OF REPRODUCTIVE ISOLATION BETWEEN CLOSELY RELATED SPECIES OF ENDEMIC HAWAIIAN *DROSOPHILA*

Elysse M. Craddock

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The drosophilid fauna of the Hawaiian Islands offers unique opportunities for study of the evolution of reproductive barriers. Speciation in this group has been very extensive and comparatively recent. Furthermore, it is still actively in progress. Relationships between species in the "picture-winged" group are well known as a result of analysis of the chromosomal inversion sequences of most species. It is apparent that many of the instances of speciation have been associated with rare interisland migratory events, such that the more recently evolved species is effectively geographically isolated from its immediate ancestor. In numerous other cases, speciation has been achieved on a single island without the benefit of such a major geographic barrier, and the resulting forms are now sympatric. Although isolation between species seems to be effectively maintained in all cases, the strength and degree of such isolation is very variable, due to the several patterns of speciation involved and the range of ages of different species and species complexes. The barriers between closely related sympatric species might be expected to be much more complete than those between allopatric species, since maintenance of reproductive isolation in the former situation is biologically more critical. Laboratory hybridization tests, however, have not always confirmed this expectation. This result leads to an investigation of the factors which ensure the reproductive isolation of particular *Drosophila* species in nature, in spite of the apparently minimal genetic barriers which separate them.

COURTSHIP BEHAVIOR OF HAWAIIAN *DROSOPHILA*

H.T. Spieth

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Endemic Hawaiian *Drosophila* have evolved a lek type mating behavior which parallels that of some birds, mammals, and other insects. Each male establishes and protects a small territory to which sexually receptive females are attracted. Typically their territories are in close proximity to each other. Attraction of the females is achieved by the male's advertising activities which in most species involve pheromones although some species utilize visual display. Males defend their leks and respond aggressively to any other individuals that invade their leks. If the newcomer is another male, ritualized fighting results, whereas a female after identification is courted. If the female is sexually nonresponsive, the male quickly drives her away. Correlated with lek behavior is extraordinary male sexual dimorphism, and the dimorphic structures are invariably involved in the complex male courtship display. Some Hawaiian species do not exhibit lek behavior, almost invariably having wider geographical ranges. Apparently lek behavior and the associated high level of sexual selection have been important in the excessive speciation of the Hawaiian *Drosophila*.

PHYLOGENETIC RELATIONSHIP OF HAWAIIAN DROSOPHILIDAE BASED ON MORPHOLOGY AND ECOLOGY

K.Y. Kaneshiro

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A detailed analysis of the morphological relationships of Hawaiian drosophilid species shows that use of conventional taxonomic techniques can give a misleading interpretation of phylogenetic relationships in the endemic fauna of Hawaiian Drosophilidae. A comparative study of male genitalic structures, especially the phallic organs, can be used as a valuable tool in making a more accurate analysis of phylogenetic relationships in the Hawaiian drosophilids. Preliminary examination of the male genitalia of representatives of the nine endemic genera shows that the endemic fauna is composed of only two major lineages. The species which are presently described in separate genera are probably only species groups or, at the most, subgeneric groups of the genus *Drosophila* or of *Scaptomyza*.

Hawaiian drosophilids utilize a wide diversity of endemic plants and have adapted to various ecological habitats. Studies have shown that most of the species are host specific in their larval breeding sites ("specialists"), whereas others are able to use a wide range of host plants ("generalists"). It has also been shown that Hawaiian species are able to breed in various parts of plants such as decaying leaves, fruit, roots, and bark and also in slime flux exudations. These studies have been especially important because knowledge of the natural ovipositional sites has enabled us to culture and rear most of the picture-winged species in the laboratory and thereby enabled the other investigators to study them in more detail.

MICROHABITAT AND DISPERSAL PATTERNS OF THREE SPECIES OF *DROSOPHILA* ENDEMIC TO HAWAII

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Drosophila mimica and *D. kambysellisi*, two sibling species, and *D. imparisetae* are found in approximately equal proportions in Bird Park, Hawaii and comprise over 90% of the *Drosophila* collected in the present study. The microhabitat is extremely patchy, with species concentrated in patches of 25 m^2 to 650 m^2. Some patches are very stable, while others move about. The sibling species' habitats overlap about 26.7%, while overlap for *mimica* - *imparisetae* is 40.2%, and that for *kambysellisi* - *imparisetae* is 33.2%. Males and females may occupy different patches within the habitat of each of the species, the patches typically having about 55% overlap. All species exhibited highly non-random dispersal patterns. Males and females of *D. mimica* exhibit different dispersal responses with respect to an ecological interphase.

[This work was supported by AEC Contract AT-(40-1)-4023.]

SYMPOSIUM NO. 11

THE SUPPRESSION OF INSECT POPULATIONS BY THE RELEASE OF STERILE INDIVIDUALS

ORGANIZER: M.A. BATEMAN

THE STERILITY METHOD OF INSECT SUPPRESSION - ITS MERITS, LIMITATIONS, PROGRESS AND PROBLEMS

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The sterility method for the suppression of insect pests is in practical use to suppress or prevent the establishment of several insect pests. The technique is under development for possible use against a number of important pests and vector species in various parts of the world. The practical use of this highly sophisticated method of insect suppression demands basic information on the behavior and population ecology of the pest and rigid requirements for its application. Yet, the technique possesses inherent suppression characteristics that should prove of great value in dealing with certain major insect problems. The status of the technique for programs underway and some of the research in progress will be reviewed briefly for the screwworm, tropical fruit flies, pink bollworm, codling moth, boll weevil, tobacco hornworm, tsetse fly, certain mosquitoes, and other species.

THE FUTURE OF CHEMICAL STERILANTS IN ENTOMOLOGY; THEIR USE AGAINST POPULATIONS IN THE FIELD; MAMMALIAN TOXICITY AND HAZARDS

F.J.D. McDonald

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Chemosterilants offer a flexible and inexpensive tool not only in investigations on the sterile-male release method but also in ecological research. They can be used to replace irradiation as a sterility induction mechanism if accompanying somatic damage caused by gamma or X-rays is too severe. Many of these chemicals present no residual hazards when used properly and have been used successfully to control limited insect populations. At present, control and eradication programmes are in progress utilizing these compounds against insect pests of man, animals and crops.

ECOLOGY AND STERILE-RELEASE PROGRAMMES; THE MEASUREMENT OF RELEVANT POPULATION PROCESSES BEFORE AND DURING RELEASES; THE ASSESSMENT OF RESULTS

M.D. Proverbs

Canada Department of Agriculture, Summerland, B.C., Canada

Some of the ecological factors affecting the outcome of sterile insect release programmes will be discussed. A critical examination will be made, from the standpoint of ease and economy of application and reliability, of the procedures available for estimating rate of insect increase per generation in the field, population size of adult and immature stages before and after sterile insect release, ratios of sterile to wild insects, and other population parameters related to the success of sterile insect release programmes.

SYMPOSIUM NO. 12

PROSPECTS FOR PHYSICAL CONTROL OF INSECTS

ORGANIZER: S.W. BAILEY

THE USE OF SOUND AND LIGHT TO CONTROL THE BOLLWORM MOTH

H.R. Agee

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High frequency sound and light were evaluated as stimuli to interfere with the normal behavior of the bollworm moth and prevent economic damage to cotton. The sensitivity of the acoustic and visual receptors to frequency and stimuli intensity was determined. Behavioral responses of field-collected and laboratory-reared moths to known stimuli were evaluated in the laboratory. The most promising stimuli pattern for eliciting evasive behavioral responses were evaluated in the field. The most efficient system for eliciting moth evasive behavior was then tested in the field under heavy population pressures. It was found that moth habituation to the sound and light stimuli occurred after 5 to 10 minutes; it was also found that about 10% of the moths were unresponsive to the stimuli under all circumstances. Therefore, apparently normal feeding, mating, and ovipositing occurred at such levels that economic control was not achieved. However, if the stimuli were presented in a different manner, economic control of the bollworm moth might be possible.

THE MANIPULATION OF AIR MOVEMENT TO CONTROL INSECTS IN GROWING CROPS

T. Lewis

Rothamsted Experimental Station, Harpenden, Herts., England

Obstructions to the wind caused by natural topography, artificial and natural windbreaks, or even crop plants, affect the distribution of insects flying above crops and the numbers that alight on them. Such barriers create sheltered zones in which insects accumulate, and zones from which faster winds blow them away.

The height and permeability of windbreaks around crops determines the pattern of shelter produced, which is closely reflected by the primary patterns of infestation of the fields by winged migrants. Thus the initial distribution and later spread of many pests and some insect-borne viruses within fields, is often predictable. Data collected confirm this.

Sampling for pests that cause losses at low density should be concentrated where accumulations occur, to ensure that they are detected early. Vulnerable zones of crops could be sprayed before the primary migrants spread from them. Artificial barriers may be arranged to prevent serious infestations, and cultural practices that promote even stands encouraged.

THE USE OF SOUND FOR INSECT CONTROL

P. Belton

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Insects make use of sounds to transfer information to other insects within or outside their own species and to transmit information to and receive it from would-be predators that are often not insects. Intense sounds can be used to kill insects selectively, particularly when they are radiated through liquids and solids.

These characteristics provide a wealth of situations where sound could be used to control or manage insect pests, but as yet there is no widespread application of acoustic techniques.

Laboratory investigations and field tests, in particular those dealing with the control of moths, mosquitoes and other biting flies, and stored product insects, will be reviewed.

The type of equipment used, some of which is described in patents, and some commercially available will be discussed.

THE CONTROL OF FOOD INFESTING INSECTS BY IONIZING RADIATION

J.J. Pratt

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The biological effects of ionizating radiation vary with dose, species and life stage. Mutagenic effects have been studied extensively since Muller's classical X-ray experiments with *Drosophila* in 1927. Fecundity can be reduced by as little as 2500 rads, but higher doses are required to reduce fertility. Growth and development can be inhibited at any stage and in stages other than the one irradiated. Longevity of adults is usually reduced by radiation, but may increase in some species. At certain doses a temporary paralysis may occur with subsequent recovery followed by death one to several days later. Feeding occurs after irradiation if permanent paralysis or death does not occur rapidly. In *Tribolium*, post-irradiation feeding can extend longevity. Doses of radiation have been established in many stored-product species for producing sterility, arresting development, and rapid or delayed killing. Continuous doses are more effective than discontinuous ones and post-irradiation temperatures affect mortality. Costs vary widely depending largely on cost of irradiation facilities balanced against rate of treatment and value of the treated product.

INSECT RESPONSE TO INFRARED RADIATION AND ITS SIGNIFICANCE TO NEW CONTROL METHODS

P.S. Callahan

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Both UV and visible light profoundly influence the behavior of arthropods. The effect of IR radiation has been largely overlooked.

There are many IR frequencies emitted by mercury vapor lamps and by sources such as stimulated molecules. Quantum calculations show that molecular vibrations in the far IR will average about one quantum of vibrational energy for each molecule of stimulated gas at room temperature.

Preliminary experiments with far IR demonstrated behavioral response by species of noctuids, Polistes wasps, and fire ants. Simuliid flies, mosquitoes and rat mites responded to the 10.6 coherent CO_2 line. The corn earworm and fall armyworm moths are highly attracted to the hydrogen cyanide and water vapor coherent lines. Modern techniques for producing and detecting far IR lines give new insight into the insect dielectric array antennae. Manipulation of insect behavior utilizing such frequencies may have significance to control methods directed at insect pests.

SYMPOSIUM NO. 13

ENTOMOLOGY AND THE MANAGEMENT OF MAN'S ENVIRONMENT

ORGANIZER: L.R. CLARK

The Proceedings of the Congress Symposia on Population Management and Integrated Control will be published by the Ecological Society of Australia as Volume 1 of its Memoirs, to appear in March 1973.

THE GOALS AND THE MEANS OF RESOURCE MANAGEMENT

K.E.F. Watt

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The goal of resource management is to maximize production, given the constraint that system instability is kept within reasonable limits. The constraint has two important implications. First, the production that we decide is optimal may be far below the maximum possible. Second, the *real* constraints may be remote from the traditional concerns of agriculture or forestry. In this case, energy and fuel availability comprise the key to system stability and production.

The carrying capacity of man's environment is being increased by using fossil fuels to supplement solar radiation. Simulations suggest that an acute shortage of oil and natural gas is likely by 2000 A.D. Capital shortage may limit the development of nuclear reactors.

The implications are that, in general, we must favour techniques for raising production based on ingenuity and insight rather than energy-hungry solutions. The energy cost per unit impact of a control measure should be a major criterion in evaluating alternatives.

INSECTS AS NATURAL RESOURCES AND TOOLS OF MANAGEMENT

W.P. Stephen

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Insect species can be regarded as renewable or flow resources. Species which have been manipulated as such may be classified as (a) *primary* resources which interact to yield a product as output, e.g. the honey bee; and (b) *intermediate* resources whose interaction output is measurable only as a derived value, as in pest control by predators.

To illustrate the idea, an economic model of alfalfa seed production is presented. Pollination by a bee species (a primary resource) is the limiting input in seed production, and the subsystem of the bee and its management is modelled. Two resource species are considered - *Megachile rotundata* and *Nomia melanderi*. Ways are being sought to increase their foraging efficiency.

A consideration of developments in resource utilization in our society suggests that insects, as natural resources, may be confined ultimately to roles as decomposers, intermediate resources in food chains, and possibly units of aesthetic value.

INSECTS AS A SOURCE OF KNOWLEDGE

E.H. Smith

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The era of modern biology beginning with Darwin's "The Origin of Species" in 1859 has been based on the scientific method by which generalizations could be formulated in elucidating the unifying principles of biology.

Once the scientific method was established the appeal of insects as a source of knowledge became evident. The experience of recent years in which insecticide resistance emerged in response to the principle of natural selection suggests that we have much to learn about the response of living organisms to man's manipulation.

Many classical studies have established insects as a fruitful source of knowledge. In looking ahead to the challenge facing biologists, it seems evident that this fact will become more generally appreciated. In support of this premise, the scientific method will be reviewed as it has been applied to entomology, classical entomological studies examined and projections offered on insects as a source of knowledge and the role of entomologists in the application of this knowledge toward the betterment of mankind.

SYMPOSIUM NO. 14

THE SUBSTANCE OF MANAGEMENT: CHANGE AND STABILITY IN POPULATIONS OF INSECTS

ORGANIZER: P.W. GEIER

THE PROPER STUDY OF POPULATIONS

J.A. Bishop

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A population is a collection of living organisms that persists in time and space. Population biologists seek to elaborate rules describing the behaviour of populations. Both ecologists and geneticists are concerned in this endeavour. Recently, the geneticists have become interested in the ecological basis of the phenomena they observe. They recognize the importance of population size, and no longer believe that selective forces acting on individuals are necessarily small. On the other hand, ecologists acknowledge the sterility of dogmatic conceptions that hinder experiment. They have also profited from the realization that few organisms are genetically identical in normal populations, and that individuals respond to the environment in different ways. Selection operating on the individuals influences directly the response of a population to both its biotic and abiotic environment, through differences in the age-specific fecundity and the life tables of different genotypes. Selection may even occur at the population level. The proper study of populations calls for immediately-related genetical and ecological investigations. This was realized in essence by Charles Darwin.

POPULATION DYNAMICS, A KEY TO THE UNDERSTANDING OF INTEGRATED CONTROL

H. Klomp

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Population dynamics are studies with a view ultimately to explaining how the general levels of abundance, at which populations formed by living things persist, are determined; and why the relative numbers of such populations fluctuate as they do. The different ways in which this subject is approached include careful field studies, life-table and key-factor analysis, and model building. The capabilities and limitations of these methods, as well as their interrelations, are briefly discussed.

ON THE PROPERTIES OF ECOSYSTEMS

D.A. Crossley

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The emphasis placed by entomologists on the ecosystem concept indicates the extent to which we are adopting a holistic viewpoint. Future judgements on the feasibility of solutions to entomological problems will be based on holistic criteria. Identification of ecosystems as realities in nature may be problematic, but not, as a rule, for the agricultural entomologist. Ecosystems have unique properties, not predictable from the sum of their parts, which are amenable to measurement or experimentation. Bioenergetics has become the major tool for measuring ecosystem dynamics, partly because of the unidirectional flow of energy, as opposed to the cycling of materials.

Measurements of energy flow or material movement provide a quantitative view of ecosystem processes, but these measurements are not adequate for explaining ecosystems. In terrestrial systems, arthropods might be analogized to thermostats on electric heaters, controlling the flow of electricity but consuming only a small part of that flow. Ecosystem models will need to incorporate these controlling influences of animals, if models are to serve their purpose of predicting ecosystem behaviour.

ECOLOGY IN RELATION TO THE MANAGEMENT OF INSECTS

M.E. Solomon

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1. Crop ecosystems differ from natural ones in various aspects, some of which are important for pest control.
2. Pest management can be approached along two interconnected routes:-
(a) improvement of control by use of selective insecticides, non-insecticidal methods, natural control agents, integrated control, and modified husbandry, with close surveillance to guide the timing of control measures; and (b) through ecological study of the fauna, the crop and control measures being integral parts of the system studied; ecological investigation should suggest ways of improving control, and should lead to modelling of the system so that the value of different possibilities can be forecast.
3. Control of the sugarcane borer in Louisiana (Hensley, 1971) illustrates the management approach.
4. Pest management provides an aim, a strategy, rather than a ready-made method. It demands research and supervision. It will most readily win support in connection with major crops.

SYMPOSIUM NO. 15

STUDY OF ECOLOGICAL SYSTEMS AND MODELS FOR USE IN POPULATION MANAGEMENT

ORGANIZER: D.P. CLARK

MODELLING ECOLOGICAL SYSTEMS: LESSONS FROM STUDY OF A NATURAL THERMAL COMMUNITY

R.G. Wiegert

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Systems ecology is broadly defined as the application of mathematical modelling techniques to both the analysis and to synthesis and simulation of ecosystem dynamics.

The steps in the modelling are summarized as: (a) determination of the variables of interest in the system, (b) determining the interaction pathways that connect the variables, (c) formulating the mathematical structure of the model, i.e. the coupling equations, (d) decisions as to how the variables of interest are to be combined into the model components or "compartments" of interest and (e) providing values for the equation constants and initial conditions for the variables.

The practical problems of developing realistic compartment type models and the conditions which the mathematical model must satisfy are discussed.

An adaptable non-linear mathematical model which employs absolute value functions in order to allow for threshold effects and which also incorporates the effects of environmental heterogeneity is described.

This model has been applied in the simulation of a natural community living in alkaline thermal effluents in Yellowstone Park. Its predictive power is assessed.

EXPERIENCE IN PEST MODELLING, A REVIEW OF MODELS, USES AND FUTURE DIRECTIONS

G.R. Conway

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This paper reviews developments in the use of mathematical models in pest control during the last 12 years. Mathematical models can be characterised by (a) their generality, (b) their realism and (c) their predictive power. Although the objectives in building a particular model determine the relative importance placed on each of the criteria above, the existing models can be broadly classified as either general or specific.

The general pest models of Becker, Conway and Shoemaker are reviewed and those dealing with particular aspects such as predator-prey interactions, uses of sterile male techniques, etc., are discussed. These more general models not only serve as guides to the more specific predictive models but also contribute to a growing theory of pest control.

The theoretical and practical aspects of a number of specific models are critically reviewed.

Modelling forms part of an overall systems approach to developing strategies and tactics for pest control. How modelling fits into this approach is discussed and priorities for future work are underlined.

POPULATION MANAGEMENT OF THE CEREAL LEAF BEETLE

D.L. Haynes

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The cereal leaf beetle, *Oulema melanopus* (L.) is now distributed over a very large area in North America and is expanding each year. This exotic pest represents only one of a long list of inevitable introductions that will take place in the future. What we learn from a study of this insect will have vast implications in regard to society's treatment of this type of problem which will occur with increasing frequency in the future.

A complementary programme consisting of biological observation and modelling has been used in this investigation. The model has then been applied in management of the pest.

A systems approach has been used in constructing the model. Working with a system model breaks down the problem into discrete components so that priorities can be made on where to start, and also continually focuses attention on the measurement of parameters of control significance. The model predicts age specific mortality as a function of density and host plant response to attack.

ECOLOGICALLY AND ECONOMICALLY COMPATIBLE PEST CONTROL

H.E. Koenig

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Current agricultural practices including pest control are not ecologically feasible in the long term because they evolved under the influence of a political-economic reward system and a technological revolution that literally viewed the environment as infinite in its waste processing capabilities.

The *mass-energy* characteristics of agricultural production processes are dependent upon the physical and biological laws governing mass-energy transformation, storage and transport characteristics of identifiable system components *and* their interactions.

The application of these newer concepts and principles are illustrated in the construction of a model describing the mass-energy dynamics of the cereal leaf beetle *Oulema melanopus* (L.).

A simulation model of the dynamics of the pest and its parasites represented by a set of difference equations, is presented. A control synthesis for the temporal dynamics of the system based on Markovian processes is then made. Both models are used in the synthesis of integrated control strategies.

SYMPOSIUM NO. 16

THE SYSTEMS APPROACH TO INSECT PEST MANAGEMENT: A DEVELOPING PROGRAMME IN THE UNITED STATES OF AMERICA

ORGANIZER: P.W. GEIER

INTRODUCTION: ON THE NATURE OF PEST CONTROL

P.W. Geier

Division of Entomology, CSIRO, Canberra, A.C.T., Australia

The paradigmatic notions that govern pest control are briefly examined and an outline is sketched of the general ecology of pest situations, with a view to setting a background for the following papers in the Symposium.

RATIONALE, GUIDELINES, AND SCOPE

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A new programme of research into pest control has recently been started under the sponsorship of the US/International Biological Programme (IBP). It is supported by National Science Foundation and involves a number of Federal and State instrumentalities. This programme is meant to develop a structured, systems-oriented capability for integrated pest control in six major crops, with a view to optimizing costs/benefits ratios and to minimizing environmental pollution.

The target crops were selected for a number of reasons, such, for instance, as contribution to overall pesticides load. Included in the programme are: cotton, soybean, pines, citrus, deciduous orchards, and lucerne.

Considerations of economic injury, including population densities, damage levels, economic analysis, and total systems analysis for the major pests and complexes of pests are essential to this programme, and is the closest co-ordination of disciplines and techniques. Plant breeding, use of natural enemies, and target-selective control methods for key pests will receive special attention in the programme.

THE COTTON SYSTEM

P.L. Adkisson

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Cotton is produced under a variety of ecological conditions in the U.S.A., ranging from the irrigated deserts of the far west, to the semi-arid regions of the southwest and the humid areas of the south. Cotton is attacked by a key pest in every area in which it is grown. Approximately 40% to 50% of all insecticides used on crops in the country are applied to cotton. All of the major pests of cotton have developed resistance to one or more insecticides and, in certain regions, *Heliothis virescens* is beyond chemical control. Furthermore, insecticidal control of cotton pests produces one of the greatest single sources of pesticide pollution in the environment.

A programme has been developed which will integrate efforts of scientists in Arkansas, California, Mississippi, and Texas in a search for better methods of pest management in cotton.

PRINCIPLES, STRATEGIES, AND TACTICS OF PEST POPULATION REGULATION AND CONTROL IN PINE BARK BEETLES ECOSYSTEMS

R.W. Stark

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Pines, and the major bark beetles affecting them, were included in the U.S. programme because of the importance of forest ecosystems, and because forests lend themselves particularly well to long-term study and efficient management.

Five major universities, State agencies, and various Federal bodies, primarily the Forest Service, are involved in this sub-programme.

Four primary objectives are pursued: (1) to develop "impact models" for the evaluation of the injuriousness of bark beetles throughout their range; (2) to develop "population models" which will predict trends in beetle activity; (3) to develop systems of strategy evaluation which will permit action decisions to be made, based on the information supplied by the impact and population models; and (4) to develop methods of pest management which can define the magnitude of any problem for any set of values, suggest a strategy compatible with the ecosystem affected, and assess the results achieved in any instance for future decisions.

SYMPOSIUM NO. 17

INTEGRATED CONTROL - WHAT? WHY? HOW? WHEN?

ORGANIZER: P.W. GEIER

OBJECTIVES, METHODS, AND SCOPE OF INTEGRATED CONTROL

M.J. Way

Imperial College Field Station, Ascot, Berks., England

The term "integrated control" is defined and its meaning clarified in relation to that of other terms, notably "pest control" and "pest management". The value of the integrated control approach in grappling with the control of complexes of pests and diseases in changing agronomic conditions is discussed.

The "life table - life system - pest management" approach is criticized as being potentially unproductive and conducive to soul-destroying accumulations of field information. Whilst ecological concepts have a vital relevance to pest control, their validity must be assessed in relation to each particular problem. Stability, for instance, may be a desirable goal for one situation, but relative instability may be a justifiable means of attaining control in another. Examples are given.

A critical need exists for "borderline" research by applied ecologists. At present, there are too few people who are able to bridge the gap between practitioners blinkered by short-term needs, and ecologists with insufficient appreciation of practical situations.

APPLICATION, FEASIBILITY, AND PROSPECTS OF INTEGRATED CONTROL

P.S. Corbet

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The extent to which integrated control can be regarded as a useful approach to pest management will depend on the frequency with which its objectives are achieved, and can be expected to be realized in future, as the needs for effective crop protection escalate. The examination of representative programmes based on the integrated-control approach reveals the major constraints that limit its applicability in contemporary crop ecosystems. Our ability to remove or significantly diminish such constraints will determine whether integrated control is feasible. In situations where these constraints are severe or prohibitive, the objectives of pest management may be better served by removing the constraints, rather than by attempting to apply the principles of integrated control. This reasoning can reveal certain priorities to be observed in the science of pest management.

A CRITICAL ASSESSMENT OF CASE HISTORIES OF INTEGRATED CONTROL IN AFFLUENT ECONOMIES

Th. Wildbolz

Federal Research Station for Horticulture, Waedenswil, Switzerland

and W. Meier

Federal Research Station for Agriculture, Zurich-Reckenholz, Switzerland

Growers' interest in integrated control is determined by practical difficulties encountered in the use of conventional methods, or by the pressure of public opinion. Problems arising in the implementation of integrated control are discussed with reference to cucumber glasshouses, pome-fruit orchards, and field crops.

Acceptable procedures to deal effectively and economically with entire complexes of diseases and pests are prerequisites for the introduction of integrated control. Such procedures are difficult to develop if the current demands for heavy crop yields and uniformly high quality of produce are to be met. Additional problems are caused by the fact that success in integrated control depends on reliable forecasts of pest situations.

Whereas much of the real cost of conventional control is in fact externalized by the industries involved, this practice is no longer possible with integrated control, and the special problem arises consequently of distributing the internalized costs between all parties concerned, producers, market industries, consumers, and governments.

INTEGRATED CONTROL: A CRITICAL REVIEW OF CASE HISTORIES IN DEVELOPING ECONOMIES

B.J. Wood

Chemara Research Station, Seremban, Malaysia

Developing economies are largely synonymous with tropical countries. Tropical climates favour pests, but many species are regularly held in check by biotic agents. Like other environmental factors capable of relaxing natural controls, insecticides wrongly used can trigger pest outbreaks.

Effective management systems can be devised to exploit fully the existence of natural limiting agents, e.g., by applying selective pesticides, promoting natural enemies, modifying the environment, adjusting cultural practices, etc. Examples are given both of successes and of desirable extensions of such methods.

Pest control based solely on insecticides may succeed, but its disadvantages include cost, resistance, pollution, and toxicity, all emphasized in tropical conditions. Socio-economic constraints are discussed: they include lack of money, scarcity of trained personnel, and the land-tenure system.

SYMPOSIUM NO. 18

INSECTICIDES AND THE ENVIRONMENT

ORGANIZER: D.F. WATERHOUSE

At the time of printing Abstracts had not been received for this Symposium. Copies will be distributed at the meeting if received in time.

SYMPOSIUM NO. 19

AN ASSESSMENT OF THE CURRENT STATUS AND PROSPECTS FOR THE CONTROL OF ARTHROPODS OF MEDICAL AND VETERINARY IMPORTANCE

ORGANIZER: R.H. WHARTON

AN ASSESSMENT OF THE CURRENT STATUS AND PROSPECTS FOR THE CONTROL OF ARTHROPODS OF MEDICAL AND VETERINARY IMPORTANCE: HOUSEFLIES *(MUSCA DOMESTICA* L.)

J. Keiding

Danish Pest Infestation Laboratory, Skovbrynet, Lyngby, Denmark

The problems in housefly control are due to lack of sanitation (source reduction) and to development of multiresistance to insecticides. In many regions various organophosphorus compounds are still effective, but in some areas all available residual insecticides fail to control flies due to resistance. The prospects of getting new effective contact insecticides to which houseflies do not become resistant seem small.

Evidently fly control problems can only be solved on the basis of effective reduction of breeding sources, mainly by suitable disposal of garbage and manure.

However, insecticides remain useful as a supplement to sanitation and some control strategies are discussed, especially selective application of insecticides based on studies of housefly behaviour (attraction, preferences, resting habits, etc.)

Biological control of flies is still in the experimental stage. Some promise is shown in the utilization of predators or parasites and in the sterile male technique. Genetical control is an interesting possibility.

CURRENT STATUS AND PROSPECTS FOR THE CONTROL OF ARTHROPODS OF MEDICAL AND VETERINARY IMPORTANCE: TICKS WITH SPECIAL EMPHASIS ON *BOOPHILUS MICROPLUS*

R.H. Wharton

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Ticks continue to present medical problems, mainly in forested areas where man intrudes into an established ecosystem. Similar but more varied and widespread problems affect the livestock industries of many countries. The one-host cattle tick *Boophilus microplus*, chiefly through its transport from Asia to tropical and sub-tropical areas, presents a variety of problems. In Asia the tick, *Babesia* blood parasites and Zebu *(Bos indicus)* cattle appear to coexist in a satisfactory state of equilibrium. This has been disrupted by the importation of European *(Bos taurus)* dairy cattle. In Australia and the Americas the introduction of *B. microplus* produced unstable systems in most areas. There has been limited success with eradication but control of ticks on *B. taurus* cattle, particularly in Australia, is jeopardised because of resistance to chemicals. Management practices can assist in some circumstances and there are grounds for optimism through more widespread use of tick-resistant cattle.

THE FIGHT AGAINST *SIMULIUM DAMNOSUM:* PRESENT STATE, PERSPECTIVES FOR THE FUTURE

R. Le Berre

Medical Entomologist of ORSTOM, Bobo-Dioulasso, Upper Volta (West Africa)

In the savannah regions of Africa, onchocerciasis of man presents a major problem in health and economic planning. The major vector, *Simulium damnosum*, in its immature stages has such clearly defined ecological requirements that the breeding sites are localised and can be catalogued. This constitutes a favourable factor for the chemical control of the larvae, which is the only method used at the present time. On the other hand because of the migration of the females (more than 150 km) no centre is isolated and this prevents consideration of vector eradication.

The results obtained in the campaign of FED-OCCGE-ORMSTOM in West Africa show that with constant supervision effective control, comparable to eradication, can be obtained. These results permit the planning of control campaigns at the regional level. One project will soon be extended to seven West African States and will demand still more efficient methods and techniques based primarily on the spreading by plane of insecticides without residual or pollutant effects.

Detailed studies on the integration of methods of biological control are envisaged.

CONTROL OF *STEGOMYIA* MOSQUITOES: ACHIEVEMENTS AND PROSPECTS

G.A.H. McClelland

Department of Entomology, University of California, Davis, Calif., U.S.A.

Past attempts to control or eradicate *Aedes aegypti* and related species are briefly reviewed. The prospects for future control will be considered in the light of realistic goals, and a re-evaluation of epidemiological needs.

SYMPOSIUM NO. 20

AGRICULTURAL ENTOMOLOGY IN DEVELOPING COUNTRIES

ORGANIZER: G. PASFIELD

PEST SITUATION IN CHANGING AGRICULTURAL SYSTEMS - A REVIEW

J.L. Nickel

International Institute of Tropical Agriculture, Ibadan, Nigeria

Inter-relationships between changes in cropping systems and pest situations can be divided into three categories:

1. Farming patterns - Changes in the agroecosystem involved in moving from shifting cultivation to continuous cropping as well as changing from interplanted crops to a monoculture tend to increase the severity of pest problems, but there are some exceptions.
2. Modern technology - The impact of fertilization and irrigation, new varieties, including resistant species, farm mechanization, use of pesticides, with reference also to the development of resistance, and storage pest problems, particularly in regard to the movement from traditional subsistence agriculture to a cash economy, is discussed and illustrated.
3. Economic development - With the development of agriculture as a business, increasing productivity through use of purchased inputs such as pesticides becomes attractive, but local manufacture of pesticides is required to help improve the input/output price ratios. The transition from home consumption to sale of crops significantly alters the quality standards demanded by the consumer, thereby reducing economic threshold levels of pest populations and increasing pest problems. The raising of the general educational level associated with economic development should, however, facilitate the safer and more judicious use of pesticides.

This review indicates that economic development and the changing agricultural systems, which are essential to such development, significantly change the pest situation.

ENTOMOLOGICAL RESEARCH OBJECTIVES AND STRATEGIES IN DEVELOPING COUNTRIES

M.J. Way

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The nature of relevant basic and applied research that is required and the kinds of control strategies that are likely to be most successful in optimising crop yields in developing countries is discussed in relation to the general features of agricultural systems, the most important of which are:

1. Climate - hot or warm throughout the year but with variable rainfall as to distribution and amount and effect on control strategies for the same pest. The role of irrigation in mimicing conditions in the humid tropics will be discussed.
2. Crops - variability in susceptibility to pest attack according to stability as affected by perennial or annual habit.
3. Non-crop environment - notably plant species and proportion of non-crop to cropped area.
4. Pests and their natural enemies - with extremes represented, for example, by certain scale insects and by locusts.
5. The social and economic conditions of the farmer - mostly labour intensive, capital scarce small farms.

The outstanding problem, and likely to be accentuated under tropical conditions, arises from how to control the pests of the highly important cereal crops and other arable crops that necessitate the increasing use of insecticides. However, special opportunities exist for cultural control by manipulating cropping systems. Research objectives based on the integrated control approach are also indicated.

SYMPOSIUM NO. 21

ENTOMOLOGY OF MAJOR CHANGES IN LAND USE

ORGANIZER: T.V. BOURKE

ENTOMOLOGY OF MAJOR CHANGES IN USAGE OF TROPICAL AFRICAN SAVANNA WITH SPECIAL REFERENCE TO TSETSE FLIES (*GLOSSINA*, DIPTERA: GLOSSINIDAE)

J. Ford

Hope Department of Entomology, University Museum, Oxford, England

The words 'major changes' imply knowledge of events at the beginning of the period under discussion. In the African tropics we only know that the European impact, especially after 1820, produced violent ecological instability which is not yet over. This instability persists naturally in biotic interzones which are most susceptible to agricultural exploitation.

Probably only four categories of savanna insects could be discussed profitably. Collection of more spectacular Lepidoptera helped develop zoogeography and mimicry genetics. Crop and forest pests and insects such as termites have been studied. Some insects of medical and veterinary importance, either as disease vectors or as agents of direct damage, have received intensive investigation.

Only the last category will be considered *in extenso*, especially the tsetses. Changes in their distribution, the phenomenon of peri-domestic adaptation and the problems of tsetse-infested National Parks will be discussed.

THE ENTOMOLOGY OF MAJOR CHANGES IN USAGE OF MEDITERRANEAN TYPE SAVANNAH AND GRASSLAND COUNTRY

M.M.H. Wallace

Division of Entomology, CSIRO, W.A. Laboratories, Wembley, W.A., Australia

Land areas in Australia influenced by a Mediterranean type climate are restricted mainly to the south-western corner of Western Australia, south-eastern South Australia, and south-western Victoria. The sowing of subterranean clover (*Trifolium subterraneum*) revolutionized land usage in these areas.

Introduced pests arrived and flourished. These include *Halotydeus destructor* (Acari: Eupodidae) from South Africa, where it has also become abundant in sown pastures; *Sminthurus viridis* (Collembola: Sminthuridae) from Europe, where it is under effective biological control and relatively scarce.

Similarly, some native species multiplied explosively. One of the best examples is the pasture webworm complex, *Hednota* spp. (Lepidoptera: Crambidae). These moths maintain low densities in scattered grass tussocks in forest and woodland but responded to the vast food supply provided in sown pastures and cereal crops.

Little is known of the losses of native insects and mites through agricultural development but some recent examples are discussed.

EFFECT OF MAJOR CHANGES IN LAND USAGE ON SOIL AND LEAF LITTER INSECTS AND MICRO-ARTHROPODS

J. Balogh

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It is generally known that the number of species of soil insects and micro-arthropods and their biomass decrease as a result of land usage.

Amongst the various species, those that survive the cataclismic effects of land cultivation, irrigation and the intensive usage of fertilizers and pesticides are usually those having the most complex ecological roles. Such species can usually regain a population density equal to or above that of the pre-disturbed level quite quickly.

Unfortunately, a number of these species are agricultural pests. Thus, in most cases intensive forms of land usage promote the propagation of pest species.

Comparison of the biomass of soil and leaf litter micro-arthropods of natural, autoregulative ecosystems with the biomass of ecosystems of successively decreasing autoregulation has shown that the biomass decreases to between one-third and one-tenth of its original quantity. The decrease of the biomass is accompanied by a decrease in species diversity. Thus, during land usage, secondary soil insect- and microarthropod-communities of reduced autoregulation come into being, consisting mostly of rapidly propagating species.

Only a few research projects have examined the interactions between these secondary communities and microorganisms, and through them the influence they have on the biological condition of the soil. Further work in this field should be of high priority because of the implications for agriculture generally.

CHANGING PATTERNS IN HUMAN DISEASE PROBLEMS RESULTING FROM MAJOR CHANGES IN LAND USAGE

H.E. Paterson

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Man's exploitation of his environment has influenced the incidence of insect-borne diseases in human and domestic animal populations.

There are two principal ways in which this has occurred. Firstly, by building dams and constructing irrigation schemes he has encouraged the increase of certain vector species at a time when the local concentrations of humans and domestic animals have also been increasing. This has sometimes led to changes in the transmission dynamics of diseases. Secondly, on entering new environments in search of new agricultural land, or when exploiting natural forests, man has at times intruded into the natural transmission cycles of diseases which normally involve only wild vertebrates and insect vectors. Occasionally, such intrusions have eventually resulted in the evolution of new transmission cycles involving the disease agent, a new mosquito vector and man alone.

Examples of these situations will be provided and an attempt will be made to draw some general conclusions from them which might be of value in assessing the need for preparedness in the early stages of a scheme such as the Ord River Irrigation Scheme in tropical Western Australia.

CONGRESS SECTIONS

SECTION NO. 1

TAXONOMY, MORPHOLOGY, ZOOGEOGRAPHY, PALAEONTOLOGY

CONVENOR: E.B. BRITTON

ENTOMOLOGY AND TODAY'S PROBLEMS IN ZOOLOGICAL NOMENCLATURE

C.W. Sabrosky

Systematic Entomology Laboratory, ARS, U.S.D.A., Washington, D.C., U.S.A.

Several currently active problem areas in zoological nomenclature are discussed, especially from the standpoint of entomology. Special emphasis is placed on Article 23b (50-year rule) of the International Code of Zoological Nomenclature, with a review of its history, the resolution passed at the XIIth International Congress of Entomology (London, 1963), and the recent revision of 23b published in Declaration 43 (1970). Recent agitation for dropping gender concord, the required agreement in gender between generic and specific names, is also given special attention. The pros and cons of propositions for an Entomological Code and/or an International Commission on Entomological Nomenclature are considered. The imminence of the final International Congress of Zoology (Monaco, September 1972), and its necessary decisions on the status and future of the International Commission on Zoological Nomenclature, make it imperative that entomologists be represented and make known their views. One or more resolutions will be presented for consideration by the Entomological Congress.

COMPUTERIZATION OF THE SYNOPTIC CATALOG OF NORTH AMERICAN HYMENOPTERA

K.V. Krombein

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Hymenopterists of the Smithsonian Institution and U.S. Department of Agriculture, stationed at the National Museum of Natural History in Washington, are preparing the synoptic catalog of Hymenoptera north of Mexico for entry into a specimen-based data banking program in operation at the Museum. A data capture and storage procedure will be used which will permit type to be set in light and boldface Roman, in italics and in three different sizes by a computer-driven Linetron operation. Storage of information in the data bank also will permit a broad spectrum of users in the biological community to ask a number of sophisticated questions relating to systematics, biology, ecology and distribution of Hymenoptera. Annual updating of the data base will make possible the production of revised editions at periodic intervals when justified by the volume of new entries.

ENTOMOLOGICAL INFORMATION STORAGE AND RETRIEVAL, PARTICULARLY FOR SYSTEMATIC ENTOMOLOGY

R.H. Arnett

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The volume of current entomological literature, the problem of reaching promptly entomologists concerned with precise portions of this literature, and the retrospective search required by systematic entomologists necessitates a system compatable with modern technological advances. Such a system is under consideration by the special committee on information retrieval of the *Entomological Society of America*. The system includes full cooperation with established information centers, improvement of current techniques, education of potential users, and the generation of new working tools. Eventually an information center network for entomology may be established.

THE USE OF COMPUTER-GENERATED KEYS

E.B. Britton

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The primary function of taxonomists is to distinguish taxa and to make them identifiable by others. This means that revisionary work is of fundamental importance Descriptions of new species should as far as possible be limited to revisions. Unfortunately the difficulty of making a revision increases in more than linear propotion with the increase in number of species, and revisions of really large genera are understandably rare. The handling of data, and in particular the making of good workable keys presents formidable difficulties when the number of species becomes large.

Fortunately the use of computers now offers a solution to these problems, and the possibility of a systematic approach to the revision of genera of hundreds of species.

An example of key-making and data-handling by computer for a genus of about 150 species is described.

SOME USES OF COMPUTERS IN TAXONOMIC ENTOMOLOGY

C. Wilkinson

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Phenetic methods of classification have been applied widely by taxonomists. Now the use of computers is being extended especially into the fields of identification and control. Some universities run courses in the use of computers to Biologists.

Computer identification of insect species can be carried out efficiently and in a shorter time than by the conventional published key. Experiments are progressing to test the ability of a visual input unit to identify leaf miners of the family Nepticulidae: Lepidoptera directly from the leaf.

From records put in, the computer can print maps directly for illustrating distribution and classification, etc. Contour maps as a method of interpreting phenetic and phyletic affinities will be demonstrated.

Several methods of phenetic classification using variable numbers of characters were tested on four genera of Indo-Australian Drepanidae: Lepidoptera. Results showed that reduced characters changed their affinities but correct identification was maintained for all species.

ESTUDO DOS DIASPIDÍDEOS BRASILEIROS ATRAVÉS DE COMPUTADOR

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Baseado em trabalho anterior, apresentado no IV Congresso Brasileiro de Zoologia, em 1970, objetivando o use de computadores para sistemática e exemplificando com cochonilhas da tribo Diaspidini do Estado do Rio Grande do Sul, foi agora ampliada a pesquisa para as espécies da família Diaspididae ocorrentes em todo o Brasil.

Foram também usados cartões IBM convencionais para o preparo dos programas e dos dados; a linguagem foi o FORTRAN com processamento em computador IBM 1130 e uso de uma unidade de memória de disco.

Houve considerável aumento nos ítens de caracterização e respectivas opções, com um consequente desdobramento dos arquivos criados.

É apresentado o nôvo quadro analítico, o diagrama de blocos com a programação modificada, a listagem do programa e exemplos de diferentes resultados que podem ser obtidos com a aplicação do método, tanto na determinação de espécies como na elaboração de - listas com os mais variados propósitos.

L'IMPORTANCE DES DONNÉES MANQUANTES EN TAXONOMIE

J.P. Cancela da Fonseca

C.N.R.S., C/- Laboratoire de Biologie Végétale, Avon, France

Ce papier fait partie d'une série d'études sur les espèces du genre *Oppia* (Acarina: Oribatida).

L'affinité entre espèces a été etudiée par la méthode de Goodall. Le dégré de signification est implicite dans ce coefficient de similitude.

En conclusion:

1. Les données manquantes modifient les rapports d'affinité entre espèces; il y a une perte d'information certaine.
2. Ces modifications peuvent être plus ou moins profondes suivant le poids des caractères manquants, c'est-à-dire leur fréquence relative, moins ou plus élevée.
3. Le seuil de signification choisi (5 ou 10%) met, plus ou moins, en évidence le degré de modification introduit dans les rapports d'affinité entre espèces.
4. Les changements dans le poids relatif des caractères présents dûes au manque d'un certain nombre d'entre eux peuvent masquer les vrais rapports d'affinité, - soit que leur seuil de signification est maintenu, augmenté ou diminué.
5. La possibilité de compléter la liste des données par l'interprétation des dessins correspondants, est toujours accompagnée d'un degré d'incertitude plus ou moins important, suivant que les caractères manquants considérés sont moins ou plus tranchés.

THE RELATIONSHIPS OF THE HEMIMERINA (DERMAPTERA)

E.T. Giles

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The habits and habitat of the Hemimerina will be outlined. Earlier opinions on the affinities and classification of the group will be dealt with, particularly their recent separation, as a distinct order, from the Dermaptera.

A numerical taxonomic procedure involving 283 OTU's will be used to assess the affinities of the Hemimerina with the other orthopteroid orders. The Hemimerina will be shown to stand closer to the Forficulina-Arixeniina section of the Dermaptera than to any other orthopteroid order. Further analysis will show the inter-relationships of the Hemimerina, Forficulina and Arixeniina. It is concluded that the Hemimerina are Dermaptera.

A QUANTITATIVE APPROACH TO THE PROBLEM OF DISTRIBUTION OF DERMAPTERA

Seiroku Sakai

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A rapid method for the computation of a faunal similarity index has been designed using symbolic logic. Clustering is then performed by a modification of the method of Sokal and Sneath (1963) to find the degree of relationship of the various provinces in respect of the families of Dermaptera.

It is found that the highest similarity values for the Dermaptera faunas were obtained for the Oriental and Neotropical subregions and the values for the Ethiopian and Australian subregions were also relatively high. The results indicate that Dermaptera faunas are richer in the Southern Hemisphere than the Northern Hemisphere.

From a comprehensive consideration of both the geological aspects and the computed pattern of similarity indexes, the origin of the earwigs, especially *Labiidae*, may be located in the Malayan province including Malaya, Sumatra, Java, Borneo and the Phillipines.

The dispersal of Dermaptera seems to have proceeded along three main routes:

1. Malayan Region → India → Guinea-Congo → Panama-Brazil → Nearctic.
2a. Malayan → Angaraland [as shown by Bey-Bienko (1936)] → The Eastern center of Angaraland → Nearctic. 2b. Malayan Region → Western center of the Angaraland → European and Western Siberian.
3. Malayan Region → Australian and Oceanian subregions.

THE SURTSEY INVESTIGATION, ICELAND: THE COLONIZATION OF A NEW ISLAND

C.H. Lindroth

Zoological Institute, Lund, Sweden

The island of Surtsey, off the south coast of Iceland, appeared suddenly in November, 1963, and is still in existence. Commencing in 1965, intensive investigations have been carried out in order to follow the over-sea dispersal of animals and plants to the island and the procedure of colonization. Up to now (1971) about 170 species of terrestrial arthropods have been found - which is far above expectation - but only 3 or 4 species seem to have achieved permanent settlement. It appears that anemochorous dispersal has predominated, more than half of the forms arrived belonging to the Diptera. In a few instances hydrochorous dispersal occurred, whereas introduction with man has been of little importance. Long-range dispersal, presumably from the European Continent, has occurred among certain Lepidoptera. Possibilities of transport on the sea surface were experimentally tested. The field-work is being continued.

EVOLUTION OF CERAMBYCID BEETLES IN THE HAWAIIAN ISLANDS

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The extreme isolation of the Hawaiian Islands has provided a situation where remarkable speciation has taken place in a few groups of insects from only a few ancestors. Three natural immigrations of Cerambycidae have taken place to Hawaii. Two of these have not speciated but the third has produced over 120 species from a single ancestor which may have come from southern North America. Although 8 generic names have been proposed for the latter, these have been reduced to a single genus. There is great diversity of form and size within the complex. Many of the species-groups are represented on more than one island so there have been many founder events between islands. These beetles are narrowly host-specific in native trees and in many cases related beetles bore in the same or related trees. One-third of the native genera of woody plants are attacked.

THE SPIDER FAUNA OF GRAN CANARIA AND ITS RELATIONSHIP WITH THE FAUNAS OF OTHER ATLANTIC ISLANDS, EUROPE, AFRICA, AND ASIA

G.E.W. Schmidt

Robdorf, Bundesrepublik Deutschland

Of the 66 species of Gran Canaria so far known 9 are endemic. Of the 44 species found in 1970 31 are living on the island of Tenerife, 9 on Gomera and 4 on La Palma, Lanzarote and Fuerteventura.

29 are found in the Mediterranean area, 21 on Madeira, 17 on other Atlantic islands. 26 species are also found in Europe, 21 in Africa, 13 in Asia, 9 in America, 7 in Australia and Pacific islands.

Of the 6 newly discovered spiders, *Steatoda triangulosa* is found in the Old and New World, *Tidarren gibberosum* on Madeira and *Mesiotelus mauritanicus* in the Mediterranean region. The most southern habitat of *Theridion instabile* is Gran Canaria. *Stenaelurillus nigricauda* lives in Senegal. *Camillina gigas* is a new species. It shows close relationship to forms found in South and South-East Africa. The 3 species of *Tidarren* found in the Old World show with respect to their genital organs a great similarity, whereas the 3 species found on the American continent are distinctly different from the above group.

THE GEOGRAPHICAL DISTRIBUTION OF ANTS, PAST AND PRESENT

W.L. Brown, Jr.

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Taking into account new and impending synonymy, the world genera of Formicidae are listed by broad zoogeographical areas. The tropical ant faunas are divided arbitrarily into Neotropical, Ethiopian and Indo-Australian. Genera occurring in all 3 regions mostly also occur outside the tropics, or did during the Tertiary. When these widespread ones are excluded from consideration, there are extensive sharings of genera between Ethiopian and Indo-Australian, and between Neotropical and Indo-Australian, but none between Ethiopian and Neotropical regions. The Tertiary and Recent ant distributions so far as known seem to follow the Darlingtonian pattern of dispersal and extinction centered on the Afro-Asian tropics. Comparison of fossil faunas with Recent distributions shows that subfamily Myrmicinae has been radiating and expanding since middle Tertiary times, chiefly at the expense of Dolichoderinae. In particular during this time, the dominant genera *Pheidole* and *Crematogaster* have been actively replacing *Iridomyrmex* and relatives in a centrifugal pattern.

EVOLUTION AND BIOGEOGRAPHY OF THE ECONOMIC CACAO WEEVILS, *PANTORHYTES*, DIVISION A

J.N.L. Stibick

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Pantorhytes (Coleoptera: Curculionidae) are well known as serious cacao pests in Papua New Guinea. This paper summarizes efforts to understand the relationship of the various species. Morphological studies have shown an interlocking complex of characters based on shape, colour and distribution of scales, female spermatheca, male endophallic armature and spiculum gastrale. Ecological and distributional records give support to the evolution and close relationship of sixteen species which appear to have originated in the Kokoda Valley and spread downwards towards Popondetta, west to the Markham Valley, north to the Bismarks and the Solomons and east around Milne Bay to Queensland. Several radiations are involved. Active speciation and adaption is evident as in striking scale colour changes in one species (Woodlark to Queensland) from white to red, green and blue, or in apparent hybridization of several species from the Solomons and the Popondetta area.

THE GEOGRAPHICAL DISTRIBUTION OF THE GENUS *GUIGLIA* BENSON (1938) (HYMENOPTERA: ORUSSIDAE)

Delfa Guiglia

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The genus *Guiglia* Benson was first described from north Queensland. Seven species occur in the New Zealand and Australian region, they are:
aureola Benson (1935): "New South Wales".
bombycinis Benson (1938): "N. Queensland, Kuranda, 1000 ft. *(Typus generis)*".
coracina Benson (1955): "N. Queensland, Malanda".
coronata Rayment (1951): "Fraser Park, New South Wales".
rubricata Riek (1955): "Eight mile E. of Braidwood, N.S. Wales".
schauinslandi (Ashmead) (1903): "Chatham Is., east of New Zealand".
sericata Moçsary (1900): "New South Wales".

The first discovery of the genus *Guiglia* outside the New Zealand and Australian region was *Guiglia chiliensis* (1955) (Chile, Canelo, Santiago). This is a demonstration of the old origin of the genus and one more example of the biological links between this region and Chile connected before the first fracture of Gondwanaland, dating back to the lower Jurassic age. To the Guiglini tribe (Benson, 1955) belongs the Genus *Kulcania* Benson (1935) described of the basis of the species from Costa Rica, San José [*Kulcania costaricensis* (Bischoff, 1928)].

A SURVEY OF THE DISTRIBUTION OF TWO SPECIES OF THE FRUITFLY *DROSOPHILA* AND TWO OF ITS HYMENOPTEROUS PARASITES IN THE UNITED KINGDOM

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One thousand first-year students of the Open University, dispersed through the U.K., collaborated in a survey of *Drosophila melanogaster* Mg., *D. subobscura* Coll. and their little-known parasites *Phaenocarpa tabida* (Nees) and *Pseudeucoila bochei* Weld. in June and July 1971. Records of wild flies and of their offspring and parasites bred on banana mash demonstrated a very wide distribution of these insects.

Detailed analysis of records of 150,000 flies and 2,000 parasites bred or captured revealed that *D. melanogaster* is less common in the north than in the south of the U.K. while *D. subobscura* is common everywhere. The average numbers of *D. melanogaster* were highest when banana was exposed inside a house with a garden outside; numbers of *D. subobscura* were highest in mash exposed in a garden. Average numbers of parasites were highest where there was a garden.

Addition of yeast made banana mash more attractive to flies and a more effective medium for rearing offspring.

ZOOGEOGRAPHIC REGULARITIES IN INSECT DISTRIBUTION ON THE BALKAN PENINSULA

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The Balkan Peninsula is on the border of Mediterranean, Middle European and Pontic influences. The objective of our faunal investigations has been to establish the zoogeographic borders and frequency and abundance characteristics of insects in one insect group (Syrphidae).

(a) Fixed borders of species spreading on Balkan cannot be found. In a wide area ranging from typically Mediterranean up to the typically Middle European the number of Mediterranean and Middle European - Mediterranean species varies depending upon

duration and intensity of investigation. In both areas, the species with the widest geographic range are dominant and the proportion of Mediterranean-Middle European species increases as the conditions are more typical. Typical species are in abundance and more frequent in Middle European region than in the Mediterranean but they do appear individually even in non-typical regions.
(b) Similar regularities appear in these regions even if we analyse both the spring fauna content and the summer months fauna content. The spring fauna content in the Mediterranean region is nearer to the Middle European type than to the Mediterranean one. Mediterranean species are typical only in the summer period.
(c) Species frequency dependence upon the habit of larva-forms is noticeable by the extent to which they spread out of the typical areas. The more the species in their larval-phases are connected to the typical surroundings (e.g. growth in bulbs) the more limited is their capability for wider spreading. Borders are more flexible with the species whose larvae have less specific habit (e.g. *Ofidofagne* larvae, saprophyte larvae - *Porognus*, *Milesia* and *Eristoloides* races).

THE ZOOGEOGRAPHICAL POSITIONS OF NEW GUINEA AND NEW CALEDONIA

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New Guinea and New Caledonia each hold unique positions zoogeographically. New Guinea is rich, fairly harmonic, and has varied affinities depending on the group. New Caledonia is rich considering its size, is rather disharmonic, and has distinct relationship to New Guinea and New Zealand. New Guinea has moderately high endemism on species level and lower generic endemism. New Caledonia has very high species and generic endemism. Few species are common to New Guinea and New Caledonia, and not many genera. Certain genera or higher categories range from New Guinea to New Zealand through New Caledonia. New Caledonia has, through long isolation and moderate disharmony, preserved a number of relics, as has New Zealand. New Guinea forms a transition area between Oriental and Australian regions. Relationships are stronger in one direction or another, depending on the group. Most groups relate more to the Oriental Region. Some of these enter Australia in the rain forest areas of Queensland. Australian elements prevail in the relatively dry savanna areas of parts of southern New Guinea.

ZOOGEOGRAPHIC RELATIONSHIPS OF GEOTRUPINAE (COLEOPTERA: SCARABAEIDAE) OCCURRING IN THE SOUTHERN HEMISPHERE

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The scarabaeid subfamily Geotrupinae has four tribes, all occurring in the Northern Hemisphere but with only two in the Southern Hemisphere. The subfamily is old, with a lower Cretaceous fossil from China. Subfamily dispersal is low since few species are on oceanic islands. The Athyreini (4 genera, 75^+ species) occurs in moist subtropical and tropical areas from Mexico to northern Argentina (3 genera, 70^+ species) and from Rhodesia to eastern India (1 genus, 5 species). The Bolboceratini (25 genera, 253^+ species) is in all major faunal areas, is well adapted to semiarid conditions, and is absent from New Zealand and Madagascar. Emphasis is placed on relationships of the Australian genera with those of the Ethiopian, Oriental, and Neotropical Regions. The genera *Gilletinus* and *Bolbochromus* occur in the island archipelago north of Australia and seem to show that there was little exchange during times of low Pleistocene sea levels. A few patterns *(Bolbelasmus* and *Bolbocerosoma)* indicate Tertiary exchanges via Beringia. Most patterns indicate reduction of ranges and long isolation, especially in Australia. Continental drift does not seem to explain satisfactorily present (especially generic) patterns except possibly in the Athyreini.

THE BIOGEOGRAPHICAL ELEMENTS OF NEW ZEALAND

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New Zealand has four main biogeographical elements according to the geographic relationships and likely origin of the biota.

Oriental: It is derived from the Malayan area to the NW of New Zealand, which is a subtropical component more or less restricted to the North of parallel 38 in New Zealand and found also in Lord Howe, Norfolk, Queensland, New Caledonia, New Guinea and the Pacific. Most of it is a tropical or subtropical remnant of pre-glacial time whereby usually genera only are shared.

Australian: New Zealand lies to the East of Australia under the steady influence of a wind drift and of sea currents from the West. This is an important element which occurs throughout New Zealand and varies greatly in age.

Antarctic: Sister-groups with disjunct distribution in the cold temperate zone of the southern hemisphere are regarded as of Antarctic or Austral origin. This component is more or less restricted to the South of parallel 38, being best represented in the South Island and on the islands to the South of New Zealand. In Australia it occurs mainly in Victoria and Tasmania.

Endemic: This is a very small component which comprises only those taxa that have no known close relatives outside New Zealand.

ON THE "GENIUS LOCI"

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The "genius loci" (Heikertinger) may be defined as a concentration of parallel variations in different species of one genus, of different genera, families or even orders, in one geographical locality or region.

Parallel adaptions to climatic conditions may explain some of these variations as wing reduction or melanismus in island species, but also in other warm and humid localities as f.e. in the Sphecidae on the Black Sea coast.

Often cases however so far defy an explanation. In many Mediterranean sphecid genera a nigristic cline from west to east is found; in Masaridae a centre of nigrismus is found in Israel and Lebanon (50% of species). On the other hand, southern subspecies in anthidiine bees show more extended yellow colouring than those in the north (in Israel 33%). In many Sphecidae, Eumenidae, Chrysididae and Mutillidae, sculpture, especially punctation becomes more coarse toward the Eastern Mediterranean and is especially pronounced on islands like Cyprus and Crete.

The Eumenidae form in the Red Sea Area refugium (Uvarov) a centre of rufinismus (45% of genera and 30% of species), while flavinismus, which is prevalent in the Sahara, is rare (7%).

NEW DATA ON THE ZOOGEOGRAPHY OF PSYCHODIDAE (DIPT.)

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The geographic distribution of the genera *Pericoma, Psychoda, Telmatoscopus* and *Brunettia* has been reexamined on the basis of an extensive collection of Indian Psychodidae made by Dr. F. Schmid. The collection, extending from Kashmir to Ceylon, includes 1,350 specimens belonging to 167 species, 80% of which are new to science, and 5 genera.

Taking into account the percentage of species of each genus in the psychodid fauna of the various localities and of the affinities of the species within each genus, the new data have been compared with the existing knowledge about the world distribution of psychodidae. Of particular interest is the distribution of the genus *Pericoma,* which becomes rarer going from Kashmir to the Gulf of Manaar, is absent in Ceylon as in Indonesia, rare in New Guinea and frequent in Australia. The reduction in numbers of species of *Pericoma* from the higher to lower latitudes agrees with the available European and African data. The possible reasons for such a distribution are discussed.

PHYLOGENY AND ZOOGEOGRAPHY OF PIT SCALES OF THE GENUS *LECANODIASPIS* (HOMOPTERA: COCCOIDEA: LECANODIASPIDIDAE)

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The 52 species of *Lecanodiaspis* are divided into four species groups (named: *eucalypti, quercus, africana,* and *prosopidis*) based on morphological characters, zoogeography, and host relationships. The primitive characters are exemplified in *L. frenchi* Froggatt, of Australia, while the most highly specialized ones are among those in North America.

Members of the genus are found in all major zoogeographical regions, but are absent from Canada and most of Eurasia. The Australian region is believed to be the center of origin for the genus, with South Africa and southeastern China and Japan as secondary areas of dispersal. The Nearctic and Neotropical Regions appear to be recently occupied. Sixteen species are found in the Australian, 13 in the Ethiopian, 13 in the Nearctic and Neotropical, 6 in each the Oriental and the Palearctic Regions.

THE PHYLOGENY AND ZOOGEOGRAPHY OF THE FAMILY MEMBRACIDAE RAFINESQUE

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The family Membracidae is characterised particularly by the great development of the pronotum which often takes curious and grotesque forms. The phylogenetic position of the Membracidae and of the other families of Homoptera is still a matter of much controversy among specialists.

The phylogenetic system (in the sense of Hennig) of the Membracidae is founded upon detailed morphological, biological and zoogeographical investigations. The apomorphies of the head structure within the Membracoidea (Membracidae, Biturritidae, Nicomiidae, Aetalionidae) are compared, and the differential characters and functional significances of mesoscutellum, wings, and pronotum are discussed. By means of these characteristics it is possible to establish sister-groups within the Membracoidea and Membracidae. All known species may be classified in these sister-groups.

Zoogeographical facts corroborate the systematic organisation of the Membracidae into two groups: 1. Membracinae (distribution in America only), 2. Centrotinae (distribution in Europe, Asia, Africa, Australia, America). The geographic variation of the Membracidae is explained by continental drift.

COMPARATIVE PHENOLOGY OF TWO EASTERN NORTH AMERICAN CULICINE MOSQUITOES

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Culex (Culex) restuans Theobald and *C. (C.) salinarius* (Diptera: Culicidae) are largely sympatric species, but the former ranges considerably farther north and west in North America. Although the two species often share the same larval habitats, their phenology differs considerably. In most areas, *C. restuans* begins adult activity earlier in the year than *C. salinarius* and continues activity longer in the fall. During the summer months, adult activity of *C. restuans* slackens whereas that of *C. salinarius* is at its peak. These two species have been shown to respond entirely differently to conditioning by experimental combinations of temperature and photoperiod. We have found that the development times of several life processes (i.e., larval growth, blood digestion, ovarian development, adult emergence, blood-feeding) differ strikingly between the two species in response to temperature. Cell lines were established from ovarian tissue of the two species and time/temperature relationships for growth of the cells were determined. Zoogeographical considerations of the findings are discussed.

ZOOGEOGRAPHY OF FRUIT FLIES (DIPTERA: TEPHRITIDAE) FROM THE SOUTH PACIFIC AREA

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In a recent study of the taxonomy and zoogeography of Dacini from the South Pacific area, 117 species were studied from localities in 45 islands and north-east Australia. The number of genera, supraspecific groups, species and endemic species decreases with increasing distance from the large land mass of Papua-New Guinea along the Melanesian arc of islands towards New Caledonia and there is a corresponding increase in the proportion of endemic species. The central and western Polynesian islands have a small number of species in comparison with the islands of the Melanesian arc, and all species, except one, are endemic to the area. The south-east Polynesian islands have fewer species than central and western Polynesia and all species, except two, are endemic.

The South Pacific Dacini show strong relationships with the corresponding fauna of the Oriental Region and also a typical 'filter' effect characteristic of faunas distributed along island chains. Only a few species show relationships to the Ethiopian fauna and these appear to be more recent arrivals in the area.

A REVISED INTERPRETATION OF THE ABDOMINAL MORPHOLOGY OF INSECTS, BASED ON RECENT EXAMINATIONS OF MUSCULATURE AND INNERVATION

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Examination of the abdominal musculature and innervations in Thysanura has disclosed several characters apparently in disagreement with current ideas of the morphology of the insect abdomen. The findings are compared with the conditions in other insect Orders, using partly unpublished studies, partly published results and similar characters outside the class Insecta will be mentioned. The homodynamy in several Orders, and the homologies will be discussed, and an interpretation of certain controversial structures proposed.

THE STRUCTURE AND THE SIGNIFICANCE OF THE MALE GENITALIA IN THE *MYMARIDAE* (HYMENOPTERA: CHALCIDOIDEA)

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The structure of the male genitalia in the Mymaridae is very poorly known. In a morphological comparative study the author describes the structure and the modifications of the copulatory organ in these very small Chalcidoidea.

As in the family Trichogrammatidae the basic structure of the phallus shows surprising modifications among the genera, which appear to be of high diagnostic value for generic discrimination. Besides the phallus of chalcidoid type found in many genera (*Anagrus* Hal., *Anaphes* Hal., *Anneckia* S.R., *Caraphractus* Walk., *Chaetomymar* Oglob., *Cleruchus* Enock, *Erythmelus* Enock, *Eustochus* Hal., *Mymar* Curtis, *Ooctonus* Hal., *Patasson* Walk., *Polynema* Hal., *Stephanodes* Enock, etc.) a number of gradually and remarkably modified phallic structures have been found in others (*Arescon* Walk., *Gonatocerus* Nees, *Camptoptera* Foerst., etc.). Moreover, interspecific differences are present in the male genitalia in many genera and are of taxonomic value for the discrimination of the species, as recently emphasised by the author for the *Anagrus* spp.

REMARQUES SUR LA MUSCULATURE THORACIQUE D'*ONCOJAPYX* (APTÉRYGOTES: DIPLOURES)

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Par rapport au squelette externe de *Lepisma* celui du Japygide est un peu plus rigide: la musculature longitudinale dorsale et ventrale est plus pauvre en éléments que chez *Lepisma* malgré la multiplicité des sclérites dorsaux et sternaux permettant des mouvements ondulatoires comparables à ceux des Chilopodes; moins nombreux que chez *Lepisma*, les muscles du Japygide sont cependant plus puissants car ils interviennent dans le fouissement.

La coxa et les arcs supracoxaux évoquent la région pleurale du Chilopode *Lithobius* à dorso-ventraux peu nombreux; idem pour le Japygide aux arcs moins bien individualisés et moins mobiles que chez *Lepisma*. Cependant environ les 3/4 des muscles du Japygide sont homologables à ceux du Lépisme et confirment l'interprétation proposée pour les arcs pleuraux.

A noter l'absence, comme chez *Lithobius*, de coxo-pleuraux, de trochantéro-pleuraux et de trochantéro-notaux.

Cette simplification par rapport à *Lepisma* pourrait être corrélative à l'extrême réduction de l'arc catapleural et à l'orientation très différente du trochanter.

ANATOMIE NERVEUSE ABDOMINALE DES BLATTES CAS DE *BLABERA CRANIIFER*

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De nombreuses dissections colorées in toto par le bleu de méthylène, combinées à des coupes histologiques ont permis de détailler l'innervation des derniers segments abdominaux à partir du 6e ganglion. On décrit les différents nerfs qui se rendent aux appareils génitaux du mâle et de la femelle. On analyse certaines de leurs terminaisons particulièrement celles qui semblent jouer un rôle dans la dynamique du comportement sexuel.

THE TAXONOMIC RELATIONSHIPS OF THE REDUVIIDAE (HETEROPTERA) AS INDICATED BY THE THORACIC SKELETON

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Species examined: *Acanthaspis flavipes* Stål, *Reduvius ciliatus* Reut., *Conorhinus rubrofasciatus* (DeGeer), *Ectomocoris biguttulus* Stål, *E. cordiger* Stål, *Tribelocephala indica* (Walk.), *Onocephalus annulipes* Stål, *Onocephalus* sp.

The thoracic skeleton in Reduviidae includes a median longitudinal suture in the protergal area. The mesophragmata projects anteriorly. In the absence of acrotergite, phragmal processes, vertical sutures, and various ridges, the pterothorax is ventrally flattened and secondarily simplified. The ventral processes of the mesophragmata bear a median partition which extends into the pterothoracic lumen leaving a narrow passage for the viscera. The metapleural ostiole is absent. The anteriorly placed narrow prothoracic coxal sockets, and elongated coxae affect the prothoracic venter resulting into a narrow precoxale and large postcoxale. In addition, the arrangement of prothoracic supracoxal lobes and coxal sockets permit forceful suction. The presence of rotatory coxae, and the girdle of setae at the basicoxite of the metacoxae are fairly advanced characters. The characteristic unguitractor plate is without pulvilli. The thoracic skeleton in Reduviidae, therefore, reveals that, on the basis of the features shared by mirids and tingids, the Reduviidae have a place in the Cimicomorpha.

MORPHOLOGY AND TAXONOMY OF SOME RAJASTHAN MELOLONTHID LARVAE (COLEOPTERA: SCARABAEIDAE)

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A comparative study of some Rajasthan melolonthid larvae revealed a wide variety of structural detail. The synonymy, diagnosis, description and distribution are presented. The differences are discussed and figured. An illustrated and diagnostic key to the known species is given for the first time. A phylogenetic list of subfamilies and genera is given.

NOTES ON AFRICAN *NEOPERLA* (INS., PLECOPTERA)

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Hynes (1952) and Illies (1966) synonymized all 29 species of African Perlidae under a single name, *Neoperla spio* (Newman). In fact, African *Neoperla* belong to a number of species. Modifications of tergites 7-10 and penes distinguish males, females have specific characters in the seminal receptacle, the subgenital plate and the eggs. Externally, species are very similar and several coexist in most places. Therefore, sexes cannot be associated and many species cannot be named definitely at present. At least 15 species exist, probably more.

Many species are of extremely wide distribution in Africa and some of them apparently have their closest relatives outside Africa, in Asia. *N. africana* Klapalek belongs to a group widely distributed in the oriental region, *N. leroiana* Klapalek resembles some Chinese species, *N. spec. D* is almost indistinguishable from an unnamed Ceylonese species.

A CLASSIFICATION OF THE FAMILY AMPHIPSOCIDAE (PSOCOPTERA)

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The group Caecilietae can be conveniently divided into two families: Caeciliidae and Amphipsocidae. The latter family includes large robust forms united by several morphological characters. Family Amphipsocidae is here divided into three subfamilies, each of which is defined on several morphological features: Amphipsocinae (primarily Old World tropics), Dasydemellinae (primarily New World tropics), and one based on a new genus which I call Calocaeciliinae (southeastern Asia). Between subfamily and genus further classification is required only in Amphipsocinae, which is here divided into four tribes primarily on wing-venational features. *Dasypsocus* and its allies appear to be primitive in several respects, and the tribe including *Dasypsocus* may be based entirely on primitive features. Revision of the tribes will probably be necessary as additional material and more characters are examined.

THE TAXONOMY OF THE PIMPLINAE AND CRYPTINAE (HYMENOPTERA, PARASITICA) WITH PARTICULAR REFERENCE TO ADULT, LARVAL AND BIOLOGICAL CHARACTERS

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The traditional separation of the major subfamilies of the Ichneumonidae has been on the form of the abdomen, the length of the ovipositor and the nature of the tarsal claws.

During discussion over several months with Dr. J.F. Perkins of the British Museum we have reached the conclusion that the Pimplinae and Cryptinae are best viewed as one enormous subfamily.

The Cryptinae includes ectoparasites and endoparasites and is a huge group which is numerically difficult to handle. The genera may be grouped into subtribes but a grouping into tribes is not possible.

Within the Pimplinae, we have a group, the Pimplini, specialised as endoparasites of lepidopterous pupae. The basic structural characters of the adults, as well as those of the larvae, support the separation of the Pimplini from the ectoparasitic Pimplinae.

The ectoparasitic Pimplinae are clearly an amalgamation that intergrades with the Cryptinae. Primitive groups, such as Xoridini, clearly belong in the Cryptinae and show larger differences between tribes than is the case in the more specialised groups.

One interesting problem is the likeness between *Ischnoceros* (Pimplinae), a parasite of wood-borers, and *Echthrus* (Cryptinae), also a parasite of wood-borers. Is this merely convergence?

A REVISION OF THE GENUS *ARMIGERES* IN SOUTHEAST ASIA (DIPTERA: CULICIDAE)

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Armigeres is included in the tribe Aedini and shows a close resemblance to the subgenera *Alanstonia*, *Stegomyia* and *Pseudoarmigeres* of the genus *Aedes*. It occurs predominantly in the Indo-Malayan region and extends from India in the West, to the Solomon Islands in the Southeast and Japan to the Northwest. Only 5 species occur exclusively in the Papuan subregion. In the current review, 46 species are included in *Armigeres*, 32 in the subgenus *Armigeres* and 14 in the subgenus *Leicesteria*. Two new species are described and one synonymised.

THE ORIGIN OF THE MAYFLY FAMILY CAENIDAE (EPHEMEROPTERA)

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The family Caenidae has clearly been derived from the *Potamanthellus*-group of the Neoephemeridae through reductional selection associated with small size. The continuum of certain characters between the families Caenidae and Neoephemeridae is shown as the basis for constructing the phylogenetic pathways. Demoulin (1958), Tshernova (1970) and Landa (1972) place Caenidae as most closely allied to the Prosopistomatidae. Demoulin (op. cit.) places the Neoephemeridae in a position distant from the Caenidae, viz. near the Ephemeridae.

THE PROTONYMPH IN SYSTEMATICS OF MACRONYSSIDAE (ACARI: MESOSTIGMATA)

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Classification and identification of mesostigmatic mites have been based almost exclusively on adult morphology. The generally nest- or roost-inhabiting, parasitic Macronyssidae have an unusual life history, with the protonymph attached and feeding on the host for a period of days, the deutonymph quiescent and with larviform mouthparts and other structures, and the adults engorging rapidly. The protonymph in many species is the most frequently encountered stadium and in some species the only known stadium. Simple external structure of the protonymph permits rapid and comprehensive survey of useful taxonomic features. It is feasible to use the protonymphs extensively in generic and specific diagnosis. Nearly all species can be identified from the protonymph, particularly important because of known or potential medical or veterinary significance of macronyssids. Major diagnostic features of macronyssid protonymphs are reviewed, and examples are given on their application in generic diagnoses.

TOWARDS A REVISED SUBFAMILY CLASSIFICATION OF TENEBRIONIDAE (COLEOPTERA)

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The Tenebrionidae, comprising about 15,000 described species, is one of the largest families of insects. The higher classification within the family is unsatisfactory, and there is little agreement between existing classifications based on larvae and those based on adults (which relied largely on superficial resemblance). Study of previously unknown larvae, especially from Australia and New Zealand, and of concealed structures in adults, has permitted a revised subfamily classification which is congruent for adults and larvae, and which probably better reflects phylogenetic relationships.

The old families Alleculidae, Lagriidae and Nilionidae are not easily separated as larvae or adults from some undoubted tenebrionids, and they appear to be rather specialised offshoots from typical Tenebrionidae. They are therefore included in this family. Some forms hitherto included in Tenebrionidae (e.g. Ulodinae, *Parahelops*) differ strikingly from true tenebrionids, especially as larvae, and must be excluded from the family.

THE ROLE OF THE MUSEUM ZOOLOGICUM BOGORIENSE AS A CENTRE OF RESEARCH IN INSECT TAXONOMY

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Before the second world war the Museum Zoologicum Bogoriense in Indonesia was very active in entomological research. It had become one of the few, if not the only centre for taxonomic research on insects in the Indo-malayan archipelago. At the present these activities have come practically to a stand-still. The causes of this regression, which involve many sociological as well as scientific aspects, are analyzed.

The impact of this situation on other aspects of entomological research in neighbouring countries as well as in Indonesia, and on the progress of research in other branches of biology, are discussed.

In conclusion the importance of the revival of this museum, in its activities on insect taxonomic research, is pointed out. Its possible role and contribution to the future of entomological research, particularly in the Indo-Australian archipelago, is discussed. Methods of revival are suggested.

METHODS EVOLVED FOR THE COLLECTION AND STUDY OF THE PHORIDAE OF NEW ZEALAND

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Only fleeting reference is made to methods and materials in the very many taxonomic papers on this family. This paper will examine methods that are being used in the collection and study of material suitable for a thorough taxonomic work on New Zealand Phoridae.

A simple addition to the classical hand net which has many advantages will be described.

Malaise traps of various patterns are in use. The simpler are often as effective as the more complex. Methods of construction of trapping and rearing equipment from a range of plastic containers will be described.

Originally, early authors used dry pinned material exclusively. Nowadays both these and liquid preservations are advocated. Methods of handling, working on, and storing both will be described; some new simple techniques will be introduced.

THE SYSTEMATIC IMPORTANCE OF *HETEROJAPYX* (INSECTA: DIPLURA)

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The *Heterojapyx* constitute a small group of 8 species among the Diplura Japygoidea and are remarkable for their morphology and geographical distribution.

The sensory pattern of the antennae (trichobothria at least up to the 15th segment, apical placoid sensillae very numerous), the external lobe of the maxilla provided with a stout cylindrical process, the sub-coxal organs with a single row of sensillary setae preceded by a narrow transverse area of "glandular" pores, the great pilosity of the different parts of the body and the giantism of the individuals (the type specimen of *H. soulei*, much contracted, measures 48 mm) indubitably put *Heterojapyx* very close to *Dinjapyx* and set them clearly apart from the other Japygoidea. Furthermore, their tarsi with 2 conical ventral processes and the last pair of abdominal stigmata, very elongated and much larger than the other ones, lead us to propose a new family, Heterojapygidae.

The geographical distribution of the 8 species (New Zealand: 1, Australia: 4, Tibet: 1, Pamir: 1, Madagascar: 1) suggests a gondwanian distribution. The Heterojapyx seem to have inhabited a large area at the Carboniferous, but the dislocations and translations of the continental plates, and the correlated climatic changes, must have isolated the present species, which could be considered as relicts. It must be remembered that no unquestionable fossil Japygoidea are known.

THE DIPTERA-ACALYPTRATA OF AUSTRALIA - SOME PROBLEMS IN ORIGINS, EVOLUTION, AND CLASSIFICATION

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Because of the antiquity of the fauna and the lack of fossil evidence it is difficult to postulate origins of many of the Australian faunal elements. A large part of the Australian Diptera-Acalyptrata has relationships with the Oriental Region, though some groups are more strictly Papuan in the present distribution of their species. Apart from more widely distributed groups, a small number of taxa is shared with or closely related to New Zealand faunal elements. Close affinities with other southern lands are even fewer. Many of the Australian genera and one recognized family (Fergusoninidae) are endemic, though there is also a number of widely distributed genera in some families. The indigenous Australian Heleomyzidae belong entirely to endemic genera, except for the extension of one native genus to New Guinea. Two extraordinary endemic genera appear related to Anthomyzidae and Aulacigastridae. A few of the Australian species belong to families having a widely disjunct world distribution (e.g. Teratomyzidae, Pseudopomyzidae). The best represented families in the fauna are Chloropidae, Lauxaniidae, Platystomatidae, Tephritidae, and Pyrgotidae. The taxonomic treatment of Australian species agreeing, at least superficially, with such widely distributed genera as *Sapromyza, Meiosimyza (= Lyciella), Chlorops, Lioscinella* poses a difficult problem.

THE CONNECTION BETWEEN THE PHYLOGENY OF THE PSYLLOMORPHA (HOMOPTERA) AND THEIR ALIMENTARY ADAPTATION TO HOST PLANTS

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The morphogenesis of the Psyllomorpha makes it possible to establish their relationship with the ancient Archescytinoidea. Large Archescytinoidea had a long ovipositor, curled up in a membranous bag under the abdomen, which served probably for oviposition into the reproductive organs of the plant; these opened up at the maturation of the capule and the synangium of the Medullosaceae, or the strobiles of the Cordaites and the Vojnovskyales. Extinction of large Archescytinoidea was probably connected with the disappearance of the Pteridosperms and Vojnovskyales, or with the diminishing of the size of the Cordaites. Small Archescytinoidea with a reduced ovipositor lived probably on the smaller Cordaites. Some migrated to the Coniferales, others possibly preserved their primitive connection with the Pteridosperms and gave rise to the Palaeozoic Psyllomorpha. The Glossopterides existed up to the Early Triassic, and only Pincombeidae and Permopsyllidiini could have lived on them. Protopsyllidiini must have migrated to the Coniferales: Voltziaceae, Podocarpaceae, Podozamitaceae and Araucariaceae. Conservation of relations with the Coniferales is displayed in the recent Psylloidea, which either migrate or winter on them. But all the recent Psylloidea are connected with dicotyledons, and only Liviidae with monocotyledons. Liadopsyllidae, known from the Lias, lived possibly on the forbears of the angiosperms (for instance, on *Problematospermum*, Late Jurassic, Karatau). Plesiomorphic groups of recent Psyllomorpha and therefore their common ancestors, existed on Moraceae, Anacardiaceae, Rutaceae, Lauraceae and were separated in the Cretaceous.

ADAPTIVE RADIATION IN THE NESTING BEHAVIOUR OF AUSTRALIAN SAND WASPS OF THE GENUS *BEMBIX*

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Australia is inhabited by more than 70 species of *Bembix* (Hymenoptera: Sphecidae), 18 of which we studied in the field during 1969-1970. In Australia (in contrast to North America), it is common to find several species nesting together, their nests intermingled. However, each species is distinctive in its behaviour, so much so that the females can often be more readily separated on the basis of behaviour than on structure or colour. Adaptive radiation in behaviour is of two general kinds, one having to do with nest structure, the other with prey selection. The various types of nest closure, levelling, and accessory burrows have presumably evolved in response to parasite pressure. Divergence in type of prey reduces competition for food, allowing numerous species to live together. Whereas in the Northern Hemisphere all *Bembix* that have been studied prey upon flies (Diptera), several Australian species prey on bees or wasps, one on Odonata.

MECHANISMS OF KARYOTYPIC EVOLUTION IN DRAGONFLIES

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The approximately 450 species studied cytologically, representing 19 families, give some insight into the mechanisms that may have played a role in karyotypic evolution and furnish additional evidence on the phylogenetic affinities between higher taxa. The evolutionary trends are most easily recognizable in variation of the chromosome number (n ♂ = 3 - 30), DNA content of the complement, and sex determining mechanism.

Phylogenetic advancement and structural specialization generally seem to be accompanied by a gradual increase of chromosome number. The latter is characteristic on the family level. This kind of transformation does not affect the original sex determining mechanism (XO/XX). Fusions of two or more chromosomes are characteristic of some genera of different families, especially in the *Gomphidae*. They may involve the sex chromosomes, in which case the original mode of sex determination is replaced by the neo-XY/XX type.

Previously unpublished material will be discussed and models of karyotypic evolution offered.

ORIGIN AND EVOLUTION OF THE STENOGASTRINAE (SUBSOCIAL VESPOIDEA OF THE ORIENTAL AND PAPUAN REGIONS)

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On the basis of present knowledge (partly unpublished) of structure, bionomics (particularly nesting habits) and distribution of the Stenogastrinae the question will be discussed whether these wasps are correctly regarded as a subfamily of the social wasps (Vespidae) or whether they may have evolved independently from a solitary ancestor.

SUGAR MEAL AND PROTEIN-CONTAINING MEAL IN ADULT HOLOMETABOLA

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Biting flies (e.g. *Simulium*) take sugar (nectar, honeydew), using the labella, and a protein-containing meal (blood, insect juices), using the mandibles. These complementary feeding processes are traceable throughout the Holometabola. Both meals exist in Neuroptera (e.g. *Raphidia, Mantispa*), Mecoptera, mandibulate Diptera, *Micropteryx*, Hymenoptera and Coleoptera. The sugar meal is widespread, but lost in parasites and short-lived forms: Hippoboscidae, Saturniidae. The protein meal, which typically requires the mandibles, is frequently lost, with concurrent reduction of mandibles, both in individual species (e.g. arctic-adapted black flies) and many larger groups (e.g. Chironomidae, Tipuliformia, typical Lepidoptera, Trichoptera).

Primitively, sugary liquid is swept in by maxillary lobes and labium, but advanced forms probe thin films with specialized licking elements (Diptera-labella; Lepidoptera-galeae; Trichoptera-haustellum; Hymenoptera-glossa). Many insects seek dried honeydew and dissolve the sugar with saliva; this source was probably available from Permian times, long antedating floral nectar.

ISOTOMIDAE (COLLEMBOLA) AS OPPORTUNISTS

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Collembola are well known for their dependence on a high humidity for activity, yet they occur in large numbers in habitats in which lack of available water tends to be limiting, as on high mountains, in the antarctic and arid areas. Isotomidae are prominent among, and may dominate, these concentrations, as shown by data presented here from inland Australia. This is part of a larger pattern in which the proportion of Isotomid species amongst total Collembola increases as one passes away from favourable climates, with large collembolan and other faunas, towards less favourable ones with small faunas, for example from the tropics to high latitudes, from lowlands to mountains, and from wet to arid climates. Part of the success of Isotomidae in these physically unfavourable situations can be attributed to their ability to occur, facultatively, as resistant morphs. Conversely, Isotomidae appear to be susceptible to the activities of other soil and surface animals, be it competition, interference or predation. This is illustrated by an example from a climatically favourable area in the humid tropics in which Isotomidae were most numerous in habitats, and at levels of the soil profile, where the rest of the soil fauna was least well developed.

HABITAT AND SELECTION

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Differences in the types of selection operating in different habitats have been formally recognised. They distinguish r selection, for productivity, in temporary, unpredictable habitats with small faunas, and K selection, for efficiency, operating in more favourable and predictable habitats with larger faunas. K selection is associated with specialisation and relatively low reproductive rates, r selection with greater ecological plasticity, higher reproductive rates and migratory ability. A third major selection type, beyond K, was proposed from a study of the tropical staphylinid genus *Priochirus* (Coleoptera). It operates in predictably unfavourable habitats, in the case of *Priochirus*, on montane populations that have surmounted a climatic barrier, and are protected by it from interactions with other groups that seem to be important in lowland forest, in the K selection phase. Selection beyond K militates against migration and out-crossing thus conserving the adapted type. Further examples of selection beyond K, in other predictably unfavourable habitats are discussed, emphasising the low level of faunal integration, species' low reproductive rates, loss of dispersal ability, simplification of life histories, and the roles of polyploidy and parthenogenesis.

ECOLOGICAL AND ETHOLOGICAL CHARACTERS IN INSECT TAXONOMY AND PHYLOGENY

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Systematics has both analytical (discrimination and identification of taxa) and synthetical aims (elaboration of systems reflecting phylogenetic relationships). Artificial classifications may be of value for analytical purposes but for synthetical purposes only natural systems are valid. Insect system and phylogeny are built principally on the base of morphological data, which is often unsufficient. The use of physiological and biochemical data for these purposes needs plenty of the living animals under consideration and is often not effective. Besides many biochemical features are reversible in the course of phylogenesis. The use of ecological and ethological data is promising especially those data having morphological expression. The structure of cases, web-work, nests, etc. is as valuable in taxonomy as that of organs. Characters of behaviour are also suitable, especially those which can be interpreted graphically (e.g. phonograms). Mating behaviour and mode of insemination give results valuable in the characterisation of higher taxa.

Data on environment allow the appreciation of the level of organisation in comparative studies.

In the initial stages of divergence on the species level ecological characters are often more reliable than morphological ones for appreciation the splitting of a species.

BIOSYSTEMATICS OF NORTH AMERICAN AQUATIC LEPIDOPTERA (PYRALIDAE: NYMPHULINAE)

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In the Lepidoptera, adaptations for an aquatic existence are particularly advanced in the members of the pyralid subfamily Nymphulinae where not only the immature stages but even some of the adults are adapted to an aquatic existence. The North American fauna appears to divide into two groups on the basis of larval adaptation: 1. a plant-feeding group (Nymphulini); and 2. a rock-dwelling group (Argyractini). The larvae of the Nymphulini have mandibles adapted to feed upon portions of leaves whereas the Argyractini have mandibles enlarged and flattened for the purpose of scraping off algae and diatoms from submerged rocks. Gills are present or absent in the Nymphulini and cases made up of plant parts are characteristic. The larvae of the Argyractini live under silken nets on rocks, often in well-oxygenated situations and most have a full quota of blood gills. The immature forms of many species are unknown.

DIE BEDEUTUNG DER "MICROLEPIDOPTERA PALAEARCTICA" FUR DIE FORSCHUNG IN DEN NICHTPALÄARKTISCHEN GEBIETEN DER ERDE

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Mit der Herausgabe der "Microlepidoptera Palaearctica" (=MP) ist der Versuch gewagt worden, das Gesamtgebiet der palaearctischen Microlepidopteren auf eine neue systematische und nomenklatorische Basis zu stellen, die für die zukünftige Forschung grundlegend ist. Sie ist es aber weitgehend nicht nur für den paläarktischen Raum, sondern darüber hinaus für fast alle Gebiete nichtpaläarktischer Art. Wir kennen die Verzahnungen der Paläarktis mit den anderen zoogeographischen Regionen, insbesondere die nahen Beziehungen zur Nearktis und zur Orientalischen Region. Darüber hinaus wissen wir, daß über die Kordilleren und Anden hinweg eine ganze Anzahl paläarktischer Gattungen bis weit nach Sudamerika hinein verbreitet sind. Aus dem Grenzbereich der östlichen Paläarktis ist die ugemein enge Verzahnung mit der Orientalischen Fauna bekannt. Ebenso ist der Kontakt zwischen den Gebieten des Südrandes der Paläarktis und denen des tropischen Afrika und von Südafrika, besonders durch die Forschungen im Jordantal, deutlich hervorgetreten. Es genügt auf die Sesie *Melitta gephyra* Gaede und die Tineidengattung *Gephyristis* hinzuweisen, die beide aus Jericho bekannt wurden unf auf afrikanische Beziehungen hinweisen.

Die bisherige Zusammenarbeit auf weltweiter Grundlage war jedoch sehr mangelhaft, viele Syonyme entstanden dadurch. Besonders in den USA haben viele Autoren die engen Beziehungen zur Paläarktis nicht genügend berücksichtigt. Durch die Herausgabe der MP ist nunmehr für alle Autoren in nichtpaläarktischen Gebieten die wichtigste Voraussetzung für eine internationale Koordination geschaffen worden, die die Systematik und Nomenklatur auch außerhalb der Paläarktis entscheidend beeinflussen wird.

THE *DROSOPHILA MELANOGASTER* GROUP IN SOUTHEAST ASIA (DIPTERA: DROSOPHILIDAE)

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and I.R. Bock

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The *Drosophila* fauna of Southeast Asia is almost entirely restricted to two major species groups, viz., the *melanogaster* group (subgenus *Sophophora*) and the *immigrans* group (subgenus *Drosophila*). The *melanogaster* group consists of over 80 known species, most of which are endemic to Southeast Asia, many being known only from single localities. A few species are endemic to Africa, Australia, and several Pacific islands. Four species *(melanogaster, simulans, ananassae, kikkawai)* are known from Asia, Europe and/or North and South America, apparently having become widespread in association with human movements. Eleven subgroups are recognized (three of them monotypic, and another consisting of two species from Africa); by far the largest is the *montium* subgroup with over 40 known members, including various complexes of sibling species. Much of Southeast Asia remains to be sampled and further collecting will very likely reveal more new species.

ON SOME EVOLUTIONARY TRENDS IN CICADINEA NYMPHS

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Hitherto the nymphs of Homoptera Cicadinea have been considered to be undeterminable, regardless of the fact that, as in most hemimetabolic insects, their nymphs are quite similar to adults. Therefore one can generally observe in nymphs the same evolutionary trends as in adults. Nevertheless, it is possible to find some characteristics typical only of nymphs, and use them to distinguish genera and species. In some genera nymphs are even more easily distinguishable than adults.

Distinct trends can be observed in chaetotaxy. The latter can also include the sensory pits of most fulgorids. They are probably modified hairs, transformed to sense organs as a result of an adaptation to life among dense vegetation.

In Delphacidae the general trend is to increase the number of the sensory pits on the abdomen. Evidently this trend appears in several groups in parallel.

In Cicadelloidea the general trend, in contrast, is to reduce the number of setae on the body. Parallel direction of the trend can also be observed in various groups.

Similar trends can also be observed in the chaetotaxy of legs.

NATURAL SELECTION AND THE FORMATION OF MANTODEA SPECIES IN CENTRAL ASIA

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Of about 2000 known species of Mantodea the greater part inhabit the torrid zone. Two families (Mantidae, Empusidae) and 9 genera *(Mantis, Armene, Hierodula, Bolivaria, Ameles, Iris, Amblythespis, Rivetina* and *Empusa)* of mantises, including about 80 names, are represented in the U.S.S.R.

Mantis peculiarities are closely connected with their rapacious way of life and are briefly as follows: strict allopatricity of species; dependance of area on the necessary ecological niche of the species; an extreme ecological uniformity of congeneric forms, indicating their recent spreading, the archaic nature of characters as a result of absence of congestion ("group effect").

The formation of species is closely connected with the past history of the group.

The changes which took place in the connection with Tethys regression at the end of Neogene led to sharp changes in environment. A tropical environment in former times was replaced by a desert.

The main part of the superior taxons of mantises died out and only xerophilous forms remain.

Intensive formation of species in Central Asia was stimulated by orogenesis which began simultaneously with the hydro-tectonic changes.

Orography of the country, solar radiation, the nature of the soil (radiation), and high-altitude change of station and food are the most significant factors of this process today.

CYTOTAXONOMY OF THE LYGAEIDAE (HETEROPTERA)

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The chromosome cytology of over 330 species of Lygaeidae, representing 13 subfamilies has been investigated. The result so far obtained indicates that the diploid chromosome number of the Lygaeidae ranges from 10 to 30. The most frequent numbers are 14, followed by 16. Chromosome numbers are high in Cyminae and low in Rhyparochrominae.

The sex-determining mechanism is X-Y in most groups, but X-O mechanism is found consistently in Pachygronthinae and Lethaeini of Rhyparochrominae. Multiple systems occur irregularly. Quite possibly the X-O and multiple systems were derived from X-Y system.

The m-chromosomes, which show quite different behaviour from either autosomes or sex chromosomes during meiosis, are present in almost all subfamilies. However, only Lygaeinae is consistently without such chromosomes. The missing m-chromosome is apparently a derived feature.

Details of cytotaxonomic significance in the Lygaeidae will be discussed.

THE CLASSIFICATION OF THE ALEYRODIDAE (HOMOPTERA)

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The higher classification of the Aleyrodidae is based primarily on the adults while that of the lower categories is derived almost entirely from the study of immature instars. The reasons for this unusual and incongruous practice are explained, and structures useful in the classification of imagoes and immature forms are discussed.

THE GENERA OF THE VENEZUELAN ARMORED SCALE INSECTS (DIASPIDIDAE: HOMOPTERA)

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The generic classification of the Venezuelan Diaspididae is briefly revised. The association of the major groups of scale insects with the host is discussed in reference to the origin of the insect and the origin of the plant.

Representatives of Aspidiotini, Diaspidini and Odonaspidini are found in the Venezuelan fauna. In the Aspidiotini there are 17 genera present; in the Diaspidini there are 13 genera present and in the Odonaspidini 1 genus present.

The more important genera and their host relationships are discussed.

The more unusual species are illustrated, especially those endemic to the northern neotropical areas.

STUDIES ON NEW ZEALAND MIRIDAE (HEMIPTERA)

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There are many more species of Miridae in New Zealand than the 20 at present recorded. The percentage of endemic to cosmopolitan species, the relative strength of the subfamilies and tribes represented, and the host-plant relationships are discussed. The species are illustrated.

GEOLOGICALLY RECENT AND MODERN INTRODUCTIONS OF SCOLYTIDAE (COLEOPTERA) TO NORTH AMERICA

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Twenty-five species of Scolytidae have been introduced into North and Central America through commerce since records have been kept. An additional 20 species appear to have been introduced at an earlier time. Two species occur in northern North America, Asia, and Europe through natural dispersal; an additional 11 species in North America are almost indistinguishable from geographical replacement species of northern Asia and Europe and are frequently confused with them. Of the latter 13 species, 11 occur in *Picea* in subpolar areas. Of the 45 introduced species, 18 previously have not been reported in the literature or have not been recognized as introduced species. Of the 45 introduced species 10 infest seeds, 17 infest twigs, 12 infest branches, 2 infest bark of the bole, 3 infest roots, and 1 infests grass.

THE NORTH AMERICAN SPECIES OF CHALCIDOIDEA DESCRIBED BY A.A. GIRAULT

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A.A. Girault worked at the U.S. National Museum, Washington, D.C., from March 1914 until July 1917. During this time he described 488 species of North American Chalcidoidea (Hymenoptera). Types of all were deposited in the U.S.N.M. collection. Not one type is intact. Girault mutilated all his types; many he broke beyond possibility of recognition. Further, his descriptions were mostly short and uninformative. Despite this, 363 of these species have been reidentified; many of them are in the current literature. This leaves a residue of 125 species still unplaced after more than 50 years. They continue to clutter the North American catalog. It is my intention to compile a list of these still-unplaced Girault species and submit it to the Commission with a request that they be suppressed.

A FOSSIL IRONOMYIID FLY FROM CANADIAN AMBER (DIPTERA: IRONOMYIIDAE)

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A fossil fly in amber from Cedar Lake, Manitoba proves to belong to the family Ironomyiidae, heretofore known from a single Australian species, *Ironomyia nigromaculata* White, establishes that the family existed during Upper Cretaceous times in North America, and indicates it was relatively common here then.

Comparison of it and the "living fossil" from Australia shows the family appeared little different 73 Ma. than it does today; synapomorphies in their antennae, heads, thoraces, wings, legs and abdomens indicate they represent sister-genera. In points of difference the fossil species usually has the more primitive conditions.

It is postulated that the family originated in North America in late Jurassic-early Cretaceous times, whence it probably dispersed to the Holarctic and Neotropical regions, thence to Australia. Recent geophysical evidence relating to plate tectonics shows that the most plausible route for it to reach Australia was via South America and Antarctica while these three continents were contiguous-43 Ma.

TRICHOPTERA FAUNA OF THE KAMCHATKA PENINSULA

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There are 48 species of Trichoptera known in Kamchatka, 15 of which were first found by the author. Trichoptera fauna from Kamchatka is based on the Siberian complex, but the latter is much richer. Species with vast areas prevail (circumpolar or palaearctic); 4 are known only from the Kurile Islands, Primorye and Kamchatka.

Circumpolar species penetrated to North America from Asia in the Beringean Land region during the Quaternary period. The biology of one of them, *Apatania zonella* Zett. is of interest. In Europe and Canada it is represented by parthenogenetic female populations and in its native - North-East Asia both by parthenogenetic populations (in rivers) and by normal bisexual populations (in some lakes). In Kamchatka, besides male and female, a hermaphrodite specimen of the abovementioned species was found.

The more ancient relations of Asia and America are traced within Dicosmoecinae, a subfamily mainly distributed in the Nearctic, and represented in Kamchatka by the genera *Dicosmoecus*, *Ecclisomyia* and *Onocosmoecus*. The most widespread species in Kamchatka and in the Kurile Islands is *Onocosmoecus flavus*. The big larvae of this species form a large biomass and play an important role in the ecosystems of rivers.

According to the duration of life cycles, Trichoptera from Kamchatka's rivers are divided into two groups; namely with one or two year life cycles. The larvae from the first group feed on shed leaves and aquatic plants, those of the second group are carnivorous or feed on fine organisms and detritus, which are caught with the help of nets.

SYSTEMATICS OF THE AUSTRALIAN COCCID GENERA *LACHNODIUS* MASKELL AND *SPHAEROCOCCOPSIS* COCKERELL (HOMOPTERA)

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The endemic Australian coccid genera *Lachnodius* and *Sphaerococcopsis* possess anomalous morphological and biological characteristics which preclude placing them with confidence in either the Eriococcidae or Pseudococcidae, families to which they seem most closely allied. Discovery of undescribed species with characters intermediate between those of both suggests these genera constitute a compact natural group. Adult males of *Lachnodius* are morphologically similar to those of Eriococcidae but exhibit some primitive features not known in male eriococcids. Brown (1967) found that *L. eucalypti* lacked heterochromatic chromosomes which are characteristic of males in all the more specialized Coccoidea, including Eriococcidae. The genitalia of *Lachnodius* males are somewhat similar to those of African Stictococcidae, which also lack heterochromatin. The *Lachnodius* group appears to constitute a previously unrecognized family level taxon within the Coccoidea, more primitive than the Eriococcidae but probably more closely related to that family than to the Pseudococcidae.

SECTION NO. 2

GENETICS

CONVENOR: M.J. WHITTEN

INSECT GAMETOGENESIS

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In higher insects both the male and female gametocytes undergo cycles of mitosis accompanied by incomplete cytokinesis. This results in clusters of sister cells joined to one another by systems of canals: The final number of joined "cystocytes" is constant for a given species and sex. Subsequently all male cystocytes, but only one female cystocyte in a cluster completes meiosis. The remaining female cystocytes grow and transfer their cytoplasm through the canal system to the oocyte. Endomitosis in these "nurse cells" serves to multiply the cistrons that transcribe the RNA components of the ribosomes which are stored in the ooplasm in vast numbers. In the nuclei of oocytes and spermatocytes only one chromosomal replication cycle takes place, and this is generally followed by the assembly of synaptonemal complexes. Studies of aberrant forms of gametogenesis in insects possessing mutant genes that markedly influence their fertility provide insights into the genetic control of these phenomena.

CYTOGENETICS OF 13 SEX-LINKED CROSSOVER SUPPRESSORS AND 7 TRANSLOCATIONS IN THE MOSQUITO *AEDES AEGYPTI*

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Thirteen crossover suppressors and 7 translocations were isolated and established as heterozygous strains. All aberrations involve the sex determining chromosome 1 and have passed through approximately 4-20 generations. All translocations induce varying degrees of sterility. Their possible use as tools for manipulation or control of mosquito populations is discussed. Detailed cytology and genetics of these aberrations is presented.

CYTOEVOLUTION IN THE GENUS *CHIRONOMUS* (DIPTERA: NEMATOCERA)

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Comparative studies of the polytene chromosomes in the genus *Chironomus* are proving a useful means of following the evolution of the group.

The normal chromosome complement consists of four pairs of chromosomes, although in several species the number is reduced to three pairs or, in one case, to two pairs. At present the genus can be divided into nine major cytological groups which differ in the arm combinations of the chromosomes, due to the occurrence of whole arm translocations. The *pseudothummi* group, with the arm combination AE, BF, CD, G, appears to be the most common, with an apparently world-wide distribution. However, the question of whether all species with the same arm combination are necessarily related or are the result of independent translocation events, still needs to be answered. The present evidence is inconclusive.

Detailed studies of the relationships between the species within these groups are also being attempted. Currently the emphasis is on species from Europe, North America and Australasia.

LINKAGE-GROUP CHROMOSOME CORRELATIONS IN THE GERMAN COCKROACH

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The German cockroach, *Blattella germanica* (L.) (Dictyoptera), has twelve chromosome pairs with males being the heterogametic sex (XO). Through use of about thirty mutants we have tentatively established eleven of the expected twelve linkage groups. The longest is number 10, with five markers spaced along a map distance estimated at 69 units.

The meiotic chromosomes of this insect have been examined and found suitable for detailed study. It is possible to identify each chromosome individually at late pachytene by measuring chromosome lengths. This technique has also been used to identify the chromosomes involved in several reciprocal chromosome translocations which either occurred spontaneously or were produced by ionizing irradiation. The latter were without phenotypic effects, and were detected by hatch reductions.

Existing linkage-group chromosome correlations include the sex chromosome with linkage group I, chromosome 9 with group VIII, and chromosome 10 with group III. The latter two became possible with the discovery of a stock containing a spontaneous deletion of one third of chromosome 9, the heterozygotes of which are fully viable. These changes in chromosome 9 were utilized to assign mutant loci to specific chromosome areas. This work is being extended by examination of translocations involving chromosomes 9 and 11, 7 and 12, and 11 and 12.

ESTERASE VARIATION IN PARTHENOGENETIC POPULATIONS OF THE COCKROACH *PYCNOSCELUS*

W.P. Stephen

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The genus *Pycnoscelus* as presently known consists of two species, bisexual populations restricted to the Indo-Malayan Region and the Hawaiian Islands, *P. indicus*, and a series of parthenogenetic populations found in many parts of the world, *P. surinamensis*. Recently karyological studies indicate that the bisexual populations have a diploid chromosome number of 2n(♂) = 35 to 37 and 2n(♀) = 36 or 38, whereas the parthenogenetic populations range from 34 to 37 and 53-54. The distribution of some of the parthenogenetic forms appears coincident with oceanic trading routes and is highly disjunct. The analysis of esterase patterns on disc electrophoresis was undertaken on 8 populations including the bisexual from Hawaii. The striking similarity between certain representatives of disjunct parthenogenetic clones suggest possible routes of colonialization. Intrinsic population variability in esterase isozymes and allozymes are discussed. Tissue sampling for analysis is restricted to the thoracic musculature of each specimen.

SEX AND CASTE DIMORPHISM OF A QUANTITATIVE CHARACTER IN THE HONEYBEE

G.L.G. Lee

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The absence of the usual relationship between the sexes in the honeybee plus the exposure of each sex to differing cultural conditions allows partitioning of the variance of quantitative characters - in this case wing hook number. An artificially inseminated queen bee will produce both queens and workers that are full sibs but the nutritional conditions under which queens are raised "trigger" a completely different developmental pattern such that the correlation between quantitative characters is minimal. It has long been known that the variance of quantitative characters is greater in the haploid male than the diploid worker although it had not been previously determined whether this difference was genetic or environmental. Evidence will be presented to show that the variance between families is largely genetic if measurements are made on workers, while if measurements are made with drones then the between-family variance appears to be mainly environmental. The within-family variance is, as expected primarily environmental, but it must be remembered that since bees control their environment to a much greater extent than other animals, only between-colony variances have much significance. Further data showing the partitioning of variance in colonies in which workers are producing drones will also be presented.

HYBRID ZONES, NATURAL SELECTION AND GENE FLOW IN *CALOMELA BARTONI* (COLEOPTERA: CHRYSOMELIDAE)

N.D. Murray

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Ecogenetic studies in *C. bartoni* have revealed the existence of a complex pattern of geographic variation. This includes a number of zones where previously separated races have contacted one another. One of these zones will be described in detail, since it shows the importance of genetic information in detecting such situations as well as in measuring detailed patterns of introgression. Strong selective forces have also been found to act on the species, and these will be discussed in relation to theories of hybrid zone maintenance.

DISTRIBUTION OF MELANICS IN THREE SPECIES OF POLYMORPHIC MOTH NEAR LIVERPOOL U.K.

J.A. Bishop

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Melanism is widespread in British moths. The distribution of melanics in three species has been investigated. These species are the peppered moth *Biston betularia* (L.), the scalloped hazel *Gonodontis bidentata* Clerk and the pale brindled beauty *Phigalia pilosaria* Schiff. In each species the genetic basis of melanism is a single, dominant, autosomal gene. In populations of each there is a cline in frequency of melanic forms between urban regions and the adjacent rural areas of North Wales. No two clines are the same. The cline in *P. pilosaria* is closest to what one would expect of differential camouflage of melanic and non-melanics from bird predators (as postulated by Dr. H.B.D. Kettlewell) was largely responsible. The clines in other species depart markedly from this expectation. *G. bidentata* has a cline within the urban area while the melanics of *B. betularia* are found far out in rural Wales. These differences are due to behavioural, ecological and genetic factors acting differentially on the melanic and non-melanic sections of the whole population of each species. Some of these factors will be discussed.

RELATIONSHIP OF EGG SIZE TO THE RATE OF NYMPHAL GROWTH AND SEX RATIO IN THE LARGE MILKWEED BUG

R.S. Saini

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Several hundred eggs from the fertilized females of the large milkweed bug, *Oncopeltus fasciatus* (Dallas), were carefully measured and graded into small, medium, and large sizes. The nymphs from these eggs were reared under strictly controlled conditions and their weight gains regularly recorded. After the final molt, the sex ratio of the adults was determined. The small eggs produced about twice as many females as males whereas in case of the large eggs a similar ratio in favor of the males was observed. The medium-sized eggs produced about equal number of males and females. These results are significant in light of the fact that adult females in general tend to be much larger in size than the males of this species. Furthermore, our data on weight gains indicate that the progeny from the small eggs did not grow at a significantly faster rate as compared to the other two groups. The role of egg size (and yolk complement) in such sex ratio shifts and possibly in the mechanism of sex determination is largely unexplained at this time. Further work is being done at our laboratory and the data will be presented at the Congress.

A FACTOR INFLUENCING THE RARE-MALE MATING ADVANTAGE

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Drosophila pseudoobscura females and those of other species, prefer to mate with those males that are rare among the males courting them. The females appear to obtain information about the frequencies of different kinds of males by means of airborne olfactory cues, probably lipids. When the acetone extracts of homozygous Arrowhead and Chiricahua males representing different karyotypes, are subjected to thin layer chromatography (on silica gel with methylene chloride as eluent), one extra spot is observed from the acetone extract of the AR males. Extracts of AR/AR and CH/CH females were identical in chromatographic behavior but differed from those of both types of males. We are now attempting to isolate active component(s) of the AR male extracts, and to test for this frequency-dependent mating success in nature.

[Supported by PHS Research Career Award 5K3 HD09033-08.]

SEXUAL SELECTION AND ISOLATION IN *DROSOPHILA*

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The mating success of strains of *D. melanogaster* derived from the same base population and kept in isolation for over seventy generations, during a selection programme for scutellar chaetae, is discussed. Under such "geographically isolated" conditions, behavioural isolation may have been expected as the strains had diverged considerably for the morphological character.

The major behavioural change, however, was of sexual selection rather than sexual isolation as a balanced mating threshold change occurred in both sexes of one of the strains such that the females became highly receptive and the males greatly reduced in stimulation capacity.

This result is discussed in relation to sexual selection and isolation in *D. melanogaster* and other *Drosophila* species.

SOME GENE EFFECTS ON BEHAVIOUR IN *DROSOPHILA MELANOGASTER*

Stella Crossley

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Non-random mating between strains of *D. melanogaster* was used to indicate genetically controlled behavioural differences. Knowledge of the nature of these differences is of interest for evaluating their importance in speciation and for suggesting pathways of gene action on behaviour. Behaviour was measured quantitatively. Strains investigated included vestigial, black, sooty, white-eye, ebony, tan, and scabrous mutants as well as selected lines and natural populations. The results show that quantitative variations in behaviour are good indicators of behavioural mutants such as vision defective mutants.

GENETIC ANALYSIS OF DURATION OF COPULATION IN *DROSOPHILA MELANOGASTER*

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Duration of copulation is mainly male determined and so, despite a relatively low heritability, has proved amenable to detailed study. Artificial selection for high duration of copulation was more successful than for low duration of copulation, although the latter, due mainly to a reduction in the pre-transmission period, was a more stable response. Localisation studies indicated the low line response was associated with the distal region of the right arm of chromosome 2, while the high line response involved all three major chromosomes. Some evidence was obtained that this second chromosome effect acted by reducing the pre-transmission period. The significance of duration of copulation and its components will be discussed in relation to the above results.

THE GENETICS OF NEGATIVE ASSORTATIVE MATING AND COURTSHIP STIMULI IN *DROSOPHILA MELANOGASTER*

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Multiple choice mating tests comparing the mating propensity among and within inbred lines were performed for *Drosophila melanogaster*. Reduction in courtship activity, time to copulation, and negative assortative mating were all directly related to the degree of inbreeding. By the eighth generation of sib mating, there was a 75% incidence of negative assortative mating in multiple choice tests, and a marked reduction of courtship behavior among sibs. Furthermore, absence of sperm in the female indicated the attrition of inbred lines was due to failure of sibs to mate. When individuals of "sterile cultures" were allowed a chance to outcross, all were fertile and exhibited normal mating and courtship activity. Results of genetic tests on a chromosome by chromosome basis will be presented.

[This research is supported by NSF Grant GB-22770 and NIH Training Grant 5-T01 GM 00337-11-12.]

THE ABILITY OF *DROSOPHILA MELANOGASTER* (DIPTERA) TO RECOGNISE DIFFERENT GENOTYPES

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One problem in the study of behavioural interactions between insects is that of marking and identifying the participants in an encounter. Some techniques of biometrical genetics have been modified to allow the analysis of such interactions, even where specific individuals cannot be identified. These techniques are illustrated by data on the spatial distribution and preening of six inbred strains of *D. melanogaster*, which show that females behave differently towards flies from their own culture, as compared with ones from other strains or even from different cultures of the same strain.

There were differences between the strains in their reaction to the presence of such "foreign" flies and also in the response to other individuals of their own culture. This strain variation in the social interaction within cultures has implications for several methods of studying preferential mating and these are discussed in the light of further work on the sexual behaviour of the inbred strains.

MALE MATING SPEED AS A COMPONENT OF FITNESS IN *DROSOPHILA* - AND GENERAL CONCLUSIONS

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It is not possible to define fitness as an invariant parameter associated with a particular genotype or phenotype, because of the dependence of fitness on the environment and the background genes. The measurement of fitness, which can be defined as the average number of progeny left by the carriers of a given genotype relative to the number of progeny from carriers of other genotypes, poses great problems, since all contributing factors must be considered. Unfortunately, in many experimental programmes only a few fitness factors are measured, and there are limited discussions on relationships between them.

A few studies have indicated the importance of mating speed as determined by males as a component of fitness in *Drosophila*, such that in some cases it could well be the most important component. The evidence for this will be reviewed, in relation to other components of fitness.

USE OF CYTOPLASMIC INCOMPATIBILITY AND CHROMOSOME REARRANGEMENTS FOR INSECT CONTROL

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By a combination of cytoplasmic incompatibility with certain chromosomal translocations a highly effective genetical control system has been developed in the mosquito *Culex pipiens*. Data will be presented on the occurrence, nature and effect of cytoplasmic incompatibility and on the production of translocations of various kinds. Both systems, incompatibility as well as translocations, have been used in field experiments which clearly demonstrates the feasibility of control with these two genetical control systems separately. If practical experiences are available with the combined or integrated system of translocations integrated with cytoplasmic incompatibility, they will also be presented. Further developments for improvement of the integrated system, some of them already achieved, will be briefly described.

INCOMPATIBILITY IN *CULEX PIPIENS*

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All specimens of *Culex pipiens* (wide sense) are infected with a rickettsia-like microorganism *Wohlbachia pipientis*. The organism is found in mosquitoes of all stages but is most abundant in the reproductive organs. It produces a visible pathology in males, destroying many of the gonial cells, but not in females. Oocytes are infected when formed in the ovary. The mature egg contains a mass of microorganisms near the micropyle through which a sperm must pass before it reaches the oocyte nucleus. It is suggested that different strains of *Culex pipiens* may have different strains of *Wohlbachia*, and incompatibility may be due to incompatible combinations of sperms and *Wohlbachia*. A variety of experiments bearing on this hypothesis will be presented.

GENETIC STUDIES ON *CULEX TRITAENIORHYNCHUS*

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Recent investigations have revealed the remarkable potential of this virus vector mosquito as a laboratory animal for basic research as well as a useful model for programs of mosquito control. It lends itself to laboratory experimentation by showing nearly complete linkage in females and having a number of useful genetic mutants. Currently over 156 strains are being maintained: 14 wild type strains from Pakistan, Japan and Taiwan; 32 genetic marker strains including isozymes; 31 multiple marker strains; 8 chromosome 1 pericentric inversion strains; 37 translocation stocks; 44 sex-linked lethals and 1 balanced lethal system. Linkage studies have placed at least three mutants of each linkage group, and the three linkage groups have been correlated to their respective chromosomes. Single and double heterozygous translocation - inversion stocks with high sterility involving three to six chromosomes have been produced. A method to render wild type chromosomes homozygous to detect recessive (visible and lethal) mutations is available.

STUDIES ON GENETIC CONTROL OF THE MOSQUITO, *AEDES AEGYPTI*

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There is a great deal of interest currently in basic cytogenetic studies of insect vectors of disease and for the application of the knowledge thus gained for genetic control purposes. In this regard, chromosomal translocations have attracted considerable attention during recent years.

In *Aedes aegypti*, we have investigated approximately 40 radiation-induced reciprocal translocations for their break points, fertility, fecundity, transmission and competitive mating ability in laboratory and field population cages. Computer simulations using these data indicated the potential role of these translocations for genetic control under various release strategies.

Field work done under the sponsorship of the World Health Organization in Delhi, India during 1971 summer showed the genetic incorporation of a male-linked translocation and another genetic marker in two natural populations and their maintenance for several generations following the termination of the field releases. This was the first demonstration of its type among any vector species.

Details of these laboratory and field studies will be presented.

[The work reported herein received financial support from Atomic Energy Commission Contract AT(11-1)-38 with the Radiation Laboratory, University of Notre Dame, Indiana, U.S.A. and from the World Health Organization.]

STERILITY ENHANCEMENT IN THE MOSQUITO, *CULEX TRITAENIORHYNCHUS*

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Selected translocation stocks which had been recovered from previous experiments were re-irradiated in an attempt to enhance their sterilities. Every stock which was subjected to re-irradiation gave rise to two or more lines with significant enhancement in sterility. Cytologic comparisons of mitotic configurations suggest that in most cases the simple reciprocal translocations present in the original stocks were replaced by highly complex aberrations.

To further enhance sterility, males heterozygous for two independent aberrational complexes were synthesized. These males were characterized by 97% sterility. The possible advantages of these double heterozygote males in control programs over either completely sterile males or those heterozygous for only one aberrational complex are discussed.

THE PRESENT STATUS OF GENETIC CONTROL MECHANISMS IN THE HOUSE FLY, *MUSCA DOMESTICA* L.

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Cytoplasmic incompatibility, hybrid sterility, sex-ratio distortion, chromosomal segregation distortion (meiotic drive), gross chromosomal rearrangements (translocations, inversions, and compound autosomes), conditional lethal mutations (temperature sensitive lethal mutations) and deleterious and lethal mutations were examined as possible candidates for genetic control of the house fly. Progress in the laboratory in each of these areas will be briefly reviewed. No classical cases of hybrid sterility or cytoplasmic incompatibility were found. However, reproductive incompatibilities or anomalies were discovered. Sex-ratio distortions and deleterious and lethal mutations were numerous. Chromosomal segregation distortion, gross chromosomal changes, and conditional lethal mutations were induced by irradiation and chemical treatment and these areas will be emphasized. The results of population cage tests in the laboratory and field release results of house fly strains bearing chromosomal translocations will be reported. Theoretical and practical considerations concerning the use of some of the genetic methods covered will be presented.

A GENETIC APPROACH TO THE POPULATION SUPPRESSION OF *TELEOGRYLLUS COMMODUS* (WALKER)

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A genetic method for the control of *T. commodus*, based on the displacement of the diapause trait by a conditionally lethal, dominant trait, viz. non-diapause, is being investigated.

The lethal genes would be introduced into a *T. commodus* population by males of a non-diapause hybrid strain produced by crossing and back-crossing *T. commodus* and the sibling, non-diapause, species *T. oceanicus*.

Production of a hybrid strain with traits selected to cause the disruption of the ecological adaptiveness of the genetic system of *commodus* appears to be feasible and to possess considerable advantages over alternative genetic approaches proposed or tested.

One of the hybrid strains produced has the characteristic that when the hybrid males and *commodus* females are crossed, the F_1 progeny are sterile, *inter se*. However, only the females are completely sterile, the males are partially fertile. This female sterility occurs again in the next generation if the F_1 males are crossed with *commodus* females. This transmission of female sterility potentiates an independent method of population suppression rather than a supplement to the diapause elimination approach.

SECTION NO. 3

PHYSIOLOGY, CYTOLOGY, FINE STRUCTURE

CONVENOR: A.C.S. CROSSLEY

METHODS FOR THE EXAMINATION OF INSECTS IN THE SCANNING ELECTRON MICROSCOPE

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Scanning electron microscopy is becoming more popular as a technique in entomological research, especially for the production of illustrations for taxonomic descriptions. For this purpose it is desirable that examination of conventionally mounted museum specimens be as simple as possible. We have developed techniques specifically for the handling of specimens mounted on cardboard points so that they may be returned to the collection after examination. Normally specimens are coated with a thin but opaque layer of metal to form a conducting surface. However, optically transparent, anti-static sprays are available which do not mask surface coloration or internal detail and are useful when subsequent light microscopy might be necessary. Freeze-drying is used to preserve the shape of soft specimens such as soft-bodied larvae and genitalia. Stereoscopy is used routinely and is invaluable in the interpretation of intricate surface structures.

APPORT DE LA MICROSCOPIE ÉLECTRONIQUE Á BALAYAGE (SCANNING) DANS LA COMPRÉHENSION DU POLYMORPHISME ALAIRE

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Le dépôt de la cuticule par les cellules hypodermiques et la morphologie tégumentaire qui en résulte, reflètent l'ambiance hormonale dans laquelle ces deux phénomènes se sont effectués et en particulier, la présence ou l'absence d'Hormone juvénile (HJ) active. Des études au microscope électronique à balayage montrent que les différences entre le type de tégument produit en présence d'HJ active (tégument de type larvaire) et celui élaboré en absence d'HJ ou en présence d'HJ inactivée (tégument adulte) sont souvent considérables chez les *Blattaria* macroptères, en particulier, dans la famille des *Blaberidae.*

Dans cet ordre d'Insectes, à côté des espèces à ailes longues, existent des espèces *paedoptères* caractérisées par la présence à l'état adulte d'organes alaires de type larvaire (Eupaedoptères) ou même embryonnaire (Protopaedoptères) ainsi que le montre l'examen de la trachéation et de l'innervation. Des études ontogénétiques et biométriques montrent que ces adultes présentent de nombreux caractères juvéniles (morphologie des yeux, des ocelles, des cerques, croissance de divers organes etc.) et maintiennent, en particulier, leur glande ventrale à l'état imaginale.

Le microscope à balayage permet de mettre en évidence le maintien des microsculptures et des organes sensoriels caractéristiques de la vie larvaire, chez ces adultes qu'ils soient eupaedoptères ou protopaedoptères. L'injection de C.A. chez des larves du dernier stade d'espèce macroptères permet d'obtenir des individus simulant les especes eupaedoptères. L'ablation de C.A. à des stades très jeunes de cette même espèce permet d'obtenir un bloquage temporaire de la morphogenèse des ébauches alaires mais le microscope à balayage montre que ces individus sont pourvus d'un tégument de type imaginal, ce qui les éloigna des protopaedoptères.

AN SEM STUDY OF THE ANTENNAE OF PEST SPECIES OF NEW ZEALAND MOTHS (LEPIDOPTERA)

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and N.E. Flower
D.S.I.R., Nelson, New Zealand

Sensors on the antennae of moths from the Families Noctuidae and Hepialidae have been examined with the scanning electron microscope. These two families contain many of the pest species in New Zealand. Approximately ten basic types of sensors have been found. Although some of these types of sensors are remarkably constant in appearance, most of the sensors vary greatly between species. SEM micrographs will be shown to show variations illustrating the sensor types and their variations.

FINE STRUCTURE OF THE TIP OF THE LABELLAR TASTE HAIR OF BLOW FLIES

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Pauline E. Holbert
The Holbert Electron Microscopy Laboratory, Glen Ridge, New Jersey, U.S.A.

To view a chemoreceptive sensillum as a conglomeration of synapses formed with the exterior is not new but is of help in trying to find the chemosensitive locus. Gustatory particles that impinge on the surface of the synaptic cleft are then the neural transmitter substances. They succeed in a still unknown fashion to selectively change the permeability characteristics of the postsynaptic dendritic membranes which give rise to a receptor potential.

The material filling the synaptic cleft of the taste sensillum of blow flies is viscous substance that oozes out from the dendrite-free lumen of the taste hair through the main pore distad of the dendritic endings, and one or more additional pores. A small percentage of viscous substance might as well derive from the dendrite-containing lumen of the hair since both lumen merge into the main pore. The fine structure of unfolded and closed hair tips will be discussed with respect to the significance of the viscous substance as the initial site of chemoreception.

PHYSIOLOGICAL COLOUR CHANGES IN THE ELYTRA OF BEETLES

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Apart from reversible pigment migrations in the iris cells, physiological or rapidly reversible colour changes are rare among insects. Since 1929 it has been known that the cassid leaf beetle, *Coptocylla,* can change the colour of its elytra by varying the amount of water in the cuticle and thereby the thickness of the thin films responsible for the interference colours. We have recently found that many other Cassidinae can alter the interference colours of the elytra, or both pronotum and elytra, in response to a disturbance.

The hercules beetle, *Dynastes hercules,* can change the colour of its elytra from back to greenish yellow and back again all within a few minutes. It does this in a manner previously unknown among animals. Beneath an outermost transparent layer the elytra have a yellowish spongy layer about 5 μm thick. When this layer is full of air, the reflected colour is yellowish. When the spongy layer is filled with a liquid and becomes optically homogenous, the light reflected is from the black layer below. The hercules beetle is able to vary the amount of water in its elytra in response to changes in the ambient humidity.

THE CHROMATOPHORES OF SOME AUSTRALIAN ODONATA

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Physiological colour change in *Austrolestes annulosus* and *Ischnura heterosticta*, from a bright Tyndall blue to a deep purple, is effected by the migration of dark ommochrome vesicles in hypodermal chromatophores. Both the ommochrome vesicles and the Tyndall blue granules, the structures and functions of which are described, migrate through an agranular endoplasmic reticulum network. This migration occurs only in response to temperature change. In these respects, the chromatophores are very similar to the primary and secondary pigment cells of the eye.

THE CUTICULAR FINE STRUCTURE OF SOME DIPTERA EXHIBITING PHYSICAL COLORATION

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The iridescent cuticles of a number of dipteran species from the families Calliphoridae and Tachinidae have been analysed optically and with the transmission electron microscope. All the cuticles examined were found to be *optically inactive*, that is, they do not reflect circularly polarized light. The cuticular layers responsible for this phenomenon are present in the outer part of the exocuticle and can be clearly distinguished in thin sections as an alternating series of electron-opaque and electron-light lamellae. From combined measurements of the relative thicknesses of the two types of layers together with measurements of the wavelength of the normally reflected light, we have estimated values for the refractive indices of the layers. These appear to be somewhat higher than have been recorded previously.

SEX PHEROMONE PRODUCTION AND THE ULTRASTRUCTURE OF THE DEVELOPING PHEROMONE GLAND IN FEMALE INDIAN-MEAL MOTHS

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and U.E. Brady

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Structural changes in the sex pheromone gland were correlated with the various levels of sex pheromone in four immature and three adult stages of female Indian-meal moths (*Plodia interpunctella* Hübner) (Lepidoptera: Pyralidae). Light microscopy, and transmission and scanning electron microscopy studies of the gland indicate that numerous subcellular components change considerably during development from a pharate adult in the pupal stage to a mature adult. Relative amounts of crude and gas chromatograph purified extracts of abdominal tips of females at the above stages of development were estimated by bioassays with adult male *P. interpunctella*. Evidence will be presented for the modes of accumulation and transportation of the sex pheromone through the gland cell and overlying cuticle.

ALTERING WING PATTERN - LEPIDOPTERA - BY INJECTION OF CHEMICALS

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The author presents a method of obtaining changes in wing pattern in a number of lepidopteran species through intrapupal injections using various chemical compounds. He discusses the usefulness of this method, as a supplementary indicator, in research work in the following sciences:

1. Genetics - showing degree and directions of changes brought about by external factors which modify characteristics fixed by heredity and the degree of their stability.
2. Zoogeography - in studies on natural ranges of some subspecies and local forms as a supplementary indicator of variability trends, characteristic to a given unit.
3. Morphology - in research on phylogeny of wing pattern originated by Schwanwitsch.
4. Physiology - in work on action of chemical agents biologically active, and in studying a mechanism of formation of wing pattern modifications in Lepidoptera.

WATER BALANCE IN THE AMERICAN COCKROACH

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Studies involving the use of tritiated water and controlled humidities have shown that the female American cockroach undergoes harmonious cycles of ingestion and elimination during the six-day vitellogenic cycles. More water is lost through transpiration than through feces. Under desiccating conditions, water loss is reduced by regulation of transpiration.

Hemolymph volume and osmolarity are maintained relatively constantly with variations in tissue water reflecting the hydration state. Ingested water is stored for short periods in the fat body and carcass and released on specific days to the hemolymph.

The frontal ganglion is involved in control of water balance. A mechanism of control is proposed in which the frontal ganglion inhibits the activity of the terminal abdominal ganglion, thereby holding in check ventilatory rate and secretion of diuretic hormone.

WATER RELATION IN SINGLE AND GROUPS OF WORKERS OF THE TERMITES, *MACROTERMES BELLICOSUS* (SMEATHMAN) AND *TRINEVITERMES GEMINATUS* (WASM.)

Faysal Tag Eldin Abushama

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Water loss by complete transpiration in dry air (<5% RH) at 34°C expressed as percentage of the post desiccation weight was significantly higher in single workers compared to groups of five or ten workers. After 250 minutes in the dry conditions the mortality rate was 90% in case of single termites while it was 60% and 40% among the groups of five and ten respectively. In dry air (<5% RH) and at different increasing temperatures (between 27 and 45°C) the transitional temperature and the survival time were lower in singles compared to groups, (T.T. about 40.5°C in case of singles, 43°C in groups of five and 44.5°C in groups of ten). Termites desiccated in dry air at 36°C for 90 minutes showed no ability to absorb water vapour from saturated or unsaturated air. They continuously lost weight when kept in saturated air, 95%, 90%, 80% or 65% R.H.

Locomotory and respiratory activities tested in dry air and temperatures above the optimum; proved to be higher in single termites than in groups.

ROLE OF TEMPERATURE AND WATER BALANCE IN THE TERMINATION OF LARVAL DIAPAUSE IN *BISSETIA STENIELLUS* (HAMPSON) (LEPID: CRAMBIDAE)

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In nature *Bissetia steniellus* remains in diapause in the last larval instar from October to June in sugarcane stubble. In the laboratory it is possible to terminate diapause within 15 weeks by manipulation of environmental temperature and moisture.

Consistent high temperature did not exert any influence, but when the larvae were exposed to low temperatures between 5°C and 15°C for 5-8 weeks, and were then placed at 30°C or 35°C, they pupated within 10-13 weeks provided free moisture was available. If the larvae were kept at low temperatures for a longer period, the time required for the termination of diapause on exposure to higher temperatures was not reduced. At 35°C pupation was initiated after a longer time than at 30°C, the lower temperature apparently favouring appropriate water balance.

Change in moisture content during different months of the year was investigated in field specimens. In laboratory experiments termination of diapause brought about by adjusting temperature was accompanied by changes in moisture content. Studies on fat content in dry matter, and the rate of oxygen consumption in the diapause larvae, also revealed a set pattern.

THERMO-REGULATORY ROLE OF INSECT TRACHEAL SYSTEM

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Effect of temperature on *Periplaneta americana* (L.) shows that the rate and amplitude of ventilatory and synchronised spiracular movements are modified with change in temperature. Similarly, the pupae of *Dineutes indicus* (Aube) show disparate respiration precisely during morphogenetic tracheal dissociation. Tracheal architecture has close similarity with that of coil reflux condensers which function to avoid vapour loss. The kinetic process of gas transport along fine tracheal tubes follows Poiseuille's law. The rate of ventilation is adjusted to maintain fluidity of constant air pressure which is affected by change in temperature. The increased body temperature during activity provides necessary heat for the condensation of the resultant vapour. The rate of heat transfer by conduction is given by Fourier's law

$$q = U_1 \; A_1 \, \frac{\Delta \;\; t}{\Delta \;\; x}.$$

All processes of heat conduction are often surpassed by convection, radiation and vapourisation. Since increased ventilation brings about forced convection, the Grashof number also increases. The silvery glistening tracheae provide excellent radiating surface and the rate of radiation follows Stefan-Boltzmann's rule.

OSMOREGULATION OF THE MARINE LARVA OF *PHILANISUS PLEBEIUS* WALK.

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The osmotic pressure of the blood of the marine larva of *Philanisus plebeius* (Δ = 0.70°C) is much lower than that of the medium and only slightly higher than published figures for other larvae of the Order, although sodium and chloride ions contribute a greater proportion of the total. The larva is capable of maintaining its blood osmotic pressure approximately constant over a range of external salinities from 20% to at least 150% sea water. Unlike most marine insects, the permeability of its cuticle, measured by transcuticular fluxes of isotopes and by weight changes of larvae with mouth and anus sealed, is similar to that of other caddis larvae. This is perhaps associated with the need for uptake of dissolved oxygen through cuticular gills. Osmotic regulation is achieved by a high rate of uptake of the medium by drinking and the excretion of a hypertonic rectal fluid. Rectal ultrastructure is markedly different from that of other larval Trichoptera and well organised for its function.

MEMBRANE DYNAMICS AND ION TRANSPORT IN THE HINDGUT CELLS OF *EPHYDRELLA BREVISETA* LARVAE (DIPTERA)

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The hindgut of *Ephydrella breviseta* larvae is composed of two adjacent cell types. These cells show marked complementary changes in membrane organisation in response to changes in environmental salinity. The larvae are able to exist in conditions ranging from deionised water to saturated saline solution. A theory of regulation based on changes in hindgut cell architecture is presented.

SCANNING ELECTRON MICROSCOPY OF SOME ION AND WATER TRANSPORTING TISSUES

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The three dimensional structure of a number of Malpighian tubules and rectal cells is illustrated and compared with information derived from transmission electron microscopy. Current ideas of function are discussed in the light of scanning electron microscopic information.

THE PERISYMPATHETIC ORGANS OF INSECTS

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Segmentally arranged neurohemal structures, called the perisympathetic organs are present in all Insect orders investigated so far (Ephemeroptera, Odonata, Dictyoptera, Isoptera, Cheleutoptera, Orthoptera, Dermaptera, Planipennia, Trichoptera, Lepidoptera, Hymenoptera, Coleoptera, Homoptera, Heteroptera).

They are always associated with the ventral sympathetic nervous system but their aspect and location is not constant. It seems to be linked to the condensation of the ventral nerve cord and the individualisation of the sympathetic nervous system. Several morphological types have been distinguished, which evolution can be understood according to some intermediate species.

Their histological and ultrastructural aspect is typical for neurohemal organs. Neurosecretory cells are observed in some orders.

The secretory products stored in the perisympathetic organs belong mostly to the C type and originate in neurosecretory cells located in the ventral ganglia. They are basic proteins containing indolic and pyrrolic groups.

The experimental data suggest that the perisympathetic organs are not involved in the control of color change, oviposition and blood trehalose level but regulate heart beat, diuresis and tanning.

FINE STRUCTURE OF THE VASCULAR SYSTEM SUPPLYING THE ANTENNAE OF *PERIPLANETA AMERICANA*

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The accessory hearts associated with the antennae consist of an ampulla on each side of the head, which allows one-way flow of blood, a horizontal muscle connecting the two ampullae, and a vessel leading from the ampulla to the antenna. The muscle has two types of fibres and is innervated by granule-containing axons. Other axons containing neurosecretory granules travel parallel to the muscle and form a neurohaemal organ in the wall of the ampulla beneath the muscle insertion. This neurohaemal organ has numerous Herring bodies, some of which show signs of degeneration. The wall of the ampulla has thick extracellular layers which probably give elasticity to the wall, a property which is important in the pumping action of the ampulla. The vessel leading from the ampulla to the antenna is thick-walled and convoluted. The walls are two cells thick, the inner layer of cells having a highly polarized structure which is similar to other epithelia involved in water and ion transport. The structure of this system is interpreted from a functional point of view and it appears that this part of the vascular system could control the composition of the haemolymph which enters the antennae. The significance of such a control system is discussed.

ULTRASTRUCTURAL CHANGES OF THE CORPORA ALLATA IN THE PINE MOTH, *DENDROLIMUS SPECTABILIS*, DURING THE METAMORPHOSIS

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The ultrastructure of the corpora allata in the pine moth has been studied with the electron microscope, with special regard to differences between the overwintering larva and the pupa just before emergence. Activity of corpora allata was first deduced from observations on mitochondria. The most active phase was the overwintering larva, with less activity seen in the late pupal stage just before emergence, less still in the pupa just after pupation, and least of all in the pupa. Activity of corpora allata was also deduced from the state of the endoplasmic reticulum. Here the pupal stage was the most active, with less activity in the prepupa, which transformed from the mature larval stage as a result of release of ecdyson. Neurosecretory granules are stored within the axons that terminate in the gland, but are only visible in the late pupa, when they appear to stimulate the gland to release gonadotropin.

SPECIFICITY IN THE REGENERATING CERCAL NERVES OF THE HOUSE CRICKET, *ACHETA DOMESTICUS*

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The abdominal cerci of *Acheta domesticus* are sensory structures whose sensory nerves project to the giant interneurones of the abdominal nerve cord. The cerci regenerate vigorously and functional contact is reorganised with the giant interneurones, with a high degree of accuracy as estimated in records of responses elicited in response to stimulation of the cerci. The only category of abnormal connection so far recognised arises during asymmetric development of regeneration of cerci, when contralateral connections have been detected anatomically and physiologically. Dendrites of interneurones left vacant by the absence of their normal input may be invaded by non-cercal input that is not detected in the normal animal.

DETERMINATION OF RESPIRATORY QUOTIENT OF INSECTS USING TWIN CHANNEL NULL-BALANCE PARAMAGNETIC O_2 AND INFRA RED CO_2 ANALYSERS

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Using these analysers it has been possible to make continuous recordings, over two hour periods, of the O_2 consumed and CO_2 produced by single locusts. In order to simplify the measurement of the amount of gaseous exchange ball and disc integrators have been fitted to the recorders. These integrators produce impulses, proportional to the chart area, which are counted by digital strip printers. From these counts the R.Q. can be obtained for any period of the experiment, or for the entire duration of it.

So far results show that the R.Q. may be below 0.7 for a newly emerged adult male or over 1.0 when 8 days old. As the locust gets older the R.Q. gradually returns to approximately 0.7. Slides demonstrating the relationship of age to R.Q. and body fat will be shown.

EFFECTS OF ETHER VAPOR, HYPOXIA, TRYPAN BLUE INJECTIONS, AND REMOVAL OF THE ABDOMINAL NERVE CORD ON THE HEARTBEAT OF INTACT MALE *PERIPLANETA AMERICANA* ADULTS

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The heart stops in diastole, generally progressing from anterior to posterior end, in 6.5 minutes in a state of hypoxia (drowning), and in about 13 minutes in presence of strong ether vapor. Injection of 0.05 ml of 0.1% trypan blue in 0.9% NaCl generally stopped the heart in diastole within about one minute. The heart remained stopped for about 2 minutes and then began beating very irregularly. One day thereafter the heart was beating normally. After making a long, mid-ventral needle insertion in the vicinity of the nerve cord, the hearts of 5 cockroaches continued to beat in an essentially normal fashion over a period of days.

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MELANIZATION IN THE IMMUNE REACTION OF *DROSOPHILA ALGONQUIN* (DIPTERA) AGAINST THE HYMENOPTEROUS PARASITE *PSEUDEUCOILA BOCHEI*

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The immune reaction of larvae of *D. algonquin* against *P. bochei* was characterized by the melanization and encapsulation of the parasites, or by the production of melanized particles. In successful reactions the eggs of the parasite were killed before they were completely melanized and encapsulated by host hemocytes. The results of experiments to block the deposition of melanin indicate that the biochemical changes associated with melanization constitute an important part of the immune reaction of the host. The data provide additional evidence to support the idea advanced by other workers that the phenoloxidase system plays an important role in insect immunity against internal metazoan parasites. The possibility that the phenoloxidase system of the hemocytes is activated during infection by hormonal imbalance is discussed.

ASPECTS OF LOCUST NEUROMUSCULAR PHYSIOLOGY

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The mechanical responses of a locust nerve-muscle preparation to stimulation with L-glutamic acid have been investigated in some detail. Two responses can be seen, one associated with excitation of the post-synaptic membrane and one possibly involving the non-synaptic muscle membrane. Irrigation of a preparation with appropriate concentrations of glutamic acid leads to strong potentiation of the glutamate contractions.

Measurements have been made of the concentration of glutamic acid in locust haemolymph, and the means by which the post-synaptic membrane is protected from haemolymph glutamic acid have been studied. The possible role of binding proteins, structural barriers, and receptor adaptation in the protective mechanism will be discussed.

WAX SECRETION MECHANISM IN BEES OF GENERA *ANTHOPHORA* AND *EMPHORAPSIS*

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The use of wax, or wax-like linings for bee cells has been a matter of concern for investigators. *Anthophora* and its near relative *Emphoropsis* line cells with an opaque, white, waxy material. Nininger (1920) suggested that *Anthophora* lines its cells with a material derived from cephalic glands and applied with the mouthparts. However, field observations and anatomical studies indicate that this cell-lining material is secreted by a well developed gland located in the abdominal cavity and opening in the common oviduct. This gland seems to be a specialized development of the accessory gland found in honey bees and many other Hymenoptera. The fact that *Anthophora* and *Emphoropsis* are the only two genera which make a comparable cell lining and are also the only two genera with comparably large and highly specialized glands provides strong circumstantial evidence that the cell-linings are manufactured by these glands. Further evidence is provided by the fact that the contents of the glands are waxy in nature and very similar to the cell lining material.

THE CUTICLE AND CUTICULAR SECRETIONS OF AN EPIPYROPID LARVA *EPIPYROPS ANOMALA*

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The dorsal cuticle of *Epipyrops anomala* larvae is covered with a dense array of peg-like structures. A helical thread of silk-like material arises from each peg. This chemically resembles arthropodin and appears to be secreted by the epidermal cells. It is used by the larva to form a component of its pupal coccoon.

THE NUTRITION OF A VIVIPAROUS COCKROACH EMBRYO: ITS SOURCE AND METHOD OF UPTAKE

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Embryos of *Diploptera punctata* (Blattaria) increase in dry weight during development which takes place in a brood sac of the mother. The glandular epithelial wall of the brood sac produces a secretion during the gestation period. The rate of brood sac secretion has been determined by measuring the transfer of radioactive material from the mother to the embryos or alternately to filter paper substituted for embryos at intervals during the gestation period. The rate of secretion parallels the rate at which the embryos increase in dry weight. Secretion is not produced when protein synthesis is inhibited. It can be demonstrated, *in vitro*, that embryos, shortly after the closure of the dorsal body wall, take fluid into the digestive tract via the mouth. A specialization of a proximal segment of the antenna facilitates this process. It is concluded that the embryos drink nutritive secretion of the brood sac.

ASPECTS OF THE PHYSIOLOGICAL CHANGES GOVERNING THE SWARMING OF LOCUSTS

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The pheromone which initiates and controls gregarization in locusts (in particular *Locusta migratoria migratorioides* (R et F)) is discussed in the light of its known chemistry and probable site of production and action. Various factors affecting the intensity of the solitarious and gregarious phases are considered, together with the indices of such intensities, and an attempt is made to explain these results on the basis of pheromonal activity.

The role played by microelements, in particular univalent and divalent copper, and the juvenile hormone in initiating and maintaining the swarming state is postulated.

The results obtained from this study may be utilized in devising an efficient means of biological control, of future locust swarms.

STRUCTURE AND MOTILITY IN INSECT SPERMATOZOA

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The classic insect spermatozoon is an extremely elongate, flagellate cell. Three main models of tail organization have been described in it, each corresponding to a particular kind of motility. Many Apterygota, and Aphaniptera too, belong to the simplest flagellar tubule complex known, that is a 9+2 pattern. In this case a quasi-planar wave type is evoked, with a low frequency and a great length. In other insects (almost all the Pterygota studied so far) the tubule pattern is 9+9+2, and accessory ATP-asic coarse fibers are present. The single wave type generated is cylindrical helicoidal, with higher frequency and reduced length. In other Pterygota (Phasmoidea) accessory extra-axonemal bodies are present, with ATP-ase activity, and the sperm traces a doubly helical trajectory, with two kinds of waves. Other abnormal models are present in Insect sperms, biflagellate, biaxonemal, with unmotile axoneme or without axoneme. The possibility of motion in them is strictly related to the flagellar structure.

SPERM TRANSFER AND STORAGE IN *TENEBRIO MOLITOR* L.

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The secretory systems contributing to sperm transfer and storage in male and female were examined by ultrastructural and histochemical techniques, with particular attention to the male accessory glands producing the spermatophore, the spermatophore itself, the spermatheca of the female, and the spermathecal accessory gland.

Protein and lipoprotein precursors of the spermatophore are produced by the bean-shaped gland of the male and assembled into distinct layers in the ejaculatory duct. Within the female bursa, the tip of the spermatophore extends several times and ruptures in the neck of the spermatheca. Glycoprotein products of the accessory gland traverse the bursa to the spermatheca shortly thereafter. The spermatheca is an array of elastic, multi-branched cuticular ducts surrounded by a secretory epithelium. The contrasts between the bean-shaped gland (no cuticular lining), the spermatheca (whose products pass through the overlying cuticle), and the accessory gland (efferent cuticular ductules) will be discussed.

SOME INTERESTING PECULIARITIES IN THE SPERMATOGENESIS OF THE LAMPHYRID BEETLE *ASPISOMA HESPERUM* (L.)

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Aspisoma hesperum, the third species of Brasilian Lampyridae as yet studied cytologically, has 18 A + X chromosomes, and differs from the North American species investigated by Smith and Maxwell in showing a clearly octopartite tetrad from diakinesis to metaphase I in meiosis of the male. This tetrad appears as two parallel threads, each one consisting of four chromatin bodies separated by a more or less wide gap. When the partners are separated slightly, the eight chromatin bodies can be individually seen. When, on the contrary, they are tightly pressed together, only longitudinally split chromatin blocks can be distinguished. This unusual tetrad orients itself parallel to the spindle axis and divides transversely through the median constriction, in such a way that a quadripartite half-tetrad goes to each pole. The author, for reasons discussed in the present paper, considers that at least some *Aspisoma* chromosomes, at the moment they undergo pairing, are dicentric chromosomes like those reported in Hemiptera.

ON THE CHARACTERISATION OF THE STINK COMPONENTS OF HETEROPTERAN BUGS

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This paper presents results on the chemical nature of the stink components isolated by means of paper chromatography, thin layer chromatography, absorption spectra and melting point of 2,4-dinitrophenylhydrazones of the identified compounds, of some Indian Heteroptera (see Table). The new reports in this line are octanal in *Halys dentata* Fabr. and non-2-enal in *Leptocorisa varicornis* Fabr. while the presence of other compounds is found to be in conformity with the findings of earlier workers. The quantitative analysis of the components is in progress.

TABLE. Stink components of some Indian pentatomid and coreid bugs.

SPECIES STUDIED	CHEMICALS IDENTIFIED
Chrysocoris stolli Wolf. (adult)	Propanal, hexanal, prop-2-enal, but-2-enal, hex-2-enal, oct-2-enal, dec-2-enal and methyl ethyl ketone.
Chrysocoris stolli (nymph)	Tetradecanal, pent-2-enal, hex-2-enal and methyl ethyl ketone.
Placosternum urus Stål. (adult)	Propanal, butanal, but-2-enal, hex-2-enal, methyl ethyl ketone.
Cydnus indicus Westw. (adult)	Butanal, hexanal, hex-2-enal, oct-2-enal, dec-2-enal and methyl ethyl ketone.
Halys dentata Fabr. (adult)	Hexanal, octanal, dec-2-enal, and methyl ethyl ketone.
Leptocorisa varicornis Fabr. (adult)	But-2-enal, oct-2-enal, non-2-enal and dec-2-enal.

ECOLOGICAL AND PHYSIOLOGICAL FEATURES OF PERENNIAL DIAPAUSE OF THE COLORADO POTATO BEETLE (*LEPTINOTARSA DECEMLINEATA* SAY)

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All diapausing beetles of *Leptinotarsa decemlineata* potentially possess the diapause of prolonged type. However it can manifest itself and be maintained for a long time only if the beetles spent their first hibernation in light sand or sandy loam soils. Prolonged diapause is completely absent if the beetles hibernate in heavy clay soils. In natural conditions the percentage of beetles which stay in the state of perennial diapause after hibernation in sandy soils is as follows: in early first generation - 6.5, in late first generation - 0.6, and in second generation - 0.4. Hence it is most obvious in the beetles of the early first generation.

At the state of perennial diapause the beetles are characterized by: a low water content in their body, a very low intensity of gas interchange, a respiration coefficient over one, a deep suppression in the activity of tissue cytochrome oxidase and an extremely high activity of tissue catalase.

According to duration and intensity of the oxidative metabolism depression, the perennial diapause is distinguished from all the other states of physiological rest of the Colorado potato beetle (winter-, summer- and repeated diapause, winter somnolense, summer sleep); and reveals the origin of ecological and physiological processes and reactions which are controlling and maintaining this state.

ANALYSIS OF EMBRYONIC DIAPAUSE IN *AULOCARA ELLIOTTI* (THOMAS) (ORTHOPTERA: ACRIDIDAE): HISTOLOGICAL, QUANTITATIVE AND EXPERIMENTAL

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Embryos of *Aulocara elliotti* can enter diapause at several morphological stages prior to blastokinesis. Requirements for diapause termination also are variable. Both morphological and physiological aspects of diapause have been distinguished. Whereas external morphogenesis in *A. elliotti* ceases during diapause, histological evidences presented here indicate developmental changes do occur. Fat body, gonads, muscles, oenocytes and some glands of embryos in extended diapause show hypertrophy when compared with those from embryos just entering diapause. Hypertrophy of fat body has been associated with reduced endocrine activity. Therefore, experiments were conducted to determine whether diapause could be terminated or averted by juvenile hormone analogue. Epidermal differentiation was stimulated although morphogenesis was not completed. Inhibition of epidermal differentiation resulted, however, when nymphal corpus allatum glands were implanted subepidermally into embryos following yolk-engulfment. Both results indicate tissue competence to hormonal stimuli suggesting possible hormonal regulation of embryonic diapause in this species.

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THE DIAPAUSE HORMONE OF THE SILKWORM - ITS PURIFICATION AND ASSAY

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The diapause hormone responsible for the induction of embryonic diapause in *Bombyx mori* was extracted and purified from powdered heads of adult males. The powder was washed with acetone and extracted with methanol-chloroform (1:1). The extract was dissolved in butanol and washed with ether. This crude extract was injected into pupae of non-diapause egg producers and 600 µg/pupa were active to produce diapause eggs. Repeated column chromatography of the crude extracts with Sephadex LH-20 led to the presence of two hormonally active principles. One of them was obtained with one single peak, 6 µg of which were active to induce diapause in 40 per cent of the laid eggs. The crude extract was stable to heat and light but inactivated by some proteinases. However, the active principle became labile to heat and light during the course of purification.

BIOCHEMICAL CHARACTERISTICS OF FERTILE AND STERILE STRAINS OF *CALLOSOBRUCHUS MACULATUS*

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Callosobruchus maculatus an insect pest, has fertile, subfertile, or sterile strains, the latter said to represent facultative reproductive summer diapause. To investigate this claim, biochemical characteristics relevant to insect diapause were investigated. Quantitive estimations were made of total body lipids, phospholipids, cholesterol, nucleic acids, proteins and certain enzymes like acid and alkaline phosphates, and succinic dehydrogenase. Total body water content was estimated for both normal and abnormal strains.

PARTHENOGENESIS IN SOME NEW ZEALAND APHIDS (HEMIPTERA)

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Egg-laying by aphids in New Zealand takes three forms. An endemic aphid on *Nothofagus* spp. (trees) lays eggs in summer. Many exotic arboreal aphids overwinter regularly as eggs. A few crop aphids have parallel forms, overwintering either as eggs or as parthenogenetic forms.

The main pest aphids include a group of six cosmopolitan species known in New Zealand only in parthenogenetic form. Their ability to overwinter in this form is a dominating factor in early spring build-up and hence in population strength.

An examination of clones of some of these pest species on homozygous plant-host material indicates a highly variable reaction within clones, under controlled conditions. The question of what this means genetically is raised.

SECTION NO. 4

BEHAVIOUR

CONVENOR: L.B. BARTON BROWNE

SUPERPOSITION AND CLEAR ZONE EYES

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Eyes of nocturnal insects, and of skipper butterflies and some moths that are diurnal, have a wide clear zone between cones and receptor layer. Some of these clear zone eyes have a light guide across the clear zone in each ommatidium. In the dark-adapted eye, another way for light to reach receptors is freely across the clear zone. This is the only path in some eyes, e.g. aquatic beetles and skipper butterflies. These rays crossing the clear zone may (in different groups of insects) be scattered, partially focussed as in some beetles, or well-focussed as in skipper butterflies. The latter provide a text-book example of Exner's superposition eye.

DIOPTRICS OF COMPOUND EYES WITH CRYSTALLINE THREADS

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The dioptrics of eyes with crystalline threads of several species of Insects and Crustaceans have been studied with the use of an interference microscope. No superposition image was found. The threads are light guides of high index of refraction, surrounded by sheaths of low index. The diffraction patterns of several modes of wave propagation have been observed. The influence of pigment migration is accounted for by frustrated total reflection. Birefringence properties of the corneas have been studied.

ELECTROMAGNETIC PROPERTIES OF VISUAL RECEPTORS OF THE COMPOUND EYE

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The rhabdoms of insect eyes are often long cylinders with a diameter of the order of a wavelength of light in the visible spectrum. Light propagates along cylinders of these dimensions as patterns of light known as modes. The consequences of this mode propagation is discussed. In particular, we show that the physical properties of the rhabdomeres of the fly *Calliphora* can modify the absorption spectrum from that of the photopigment. We show that the angular sensitivity of the bee ommatidium is determined by the angular sensitivity of the rhabdom as well as the angular sensitivity of the dioptric apparatus. We discuss the possibility of enhanced polarization sensitivity of the bee due to electromagnetic mode rejection properties of its rhabdom.

COMPARATIVE STUDIES ON RHABDOM FINE STRUCTURES OF ARTHROPOD COMPOUND EYES

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The fine structures of rhabdoms, especially the directional arrangements of their microvilli in an ommatidium were observed by electron microscope on several kinds of insects such as cicada (*Terpnosia vacua*, Hemiptera), water skater (*Aquarius paludum*, Hemiptera), wasp (*Polistes chinensis antennalis*, Hymenoptera), butterfly (*Papilio protenor demetrius*, Lepidoptera), dragonfly (*Anax parthenope*, Odonata), diurnal moth (*Cystidia couaggaria*, Lepidoptera) and nocturnal tropical moth (*Attacs atlas*, Lepidoptera). For comparison with these insect eyes, the eyes of a few species of crustaceans such as gammarid (*Gammarus* sp., Amphipoda) and a crab (*Grapsus grapsus*, Decapoda) were also observed and their rhabdom structures are comparatively discussed. The rhabdom microvilli in the ommatidium of the nocturnal type moth are bigger but are not regularly arranged, but those of the diurnal type moth are small and regularly arranged and show the structure similar to that of the butterfly. Structural differences in rhabdom were also observed among the Hemiptera; the rhabdom of cicada shows the typical fused type rhabdom with microvilli arranged in two directions at right angles to one another within an ommatidium, but the rhabdom of water skater shows the typical open type rhabdom. In the compound eyes of diurnal insects the microvilli in the rhabdom of an ommatidium are oriented in from two to five different directions according to the species but the microvilli from a single retinular cell are arranged in a direction, which is related to the perception of a plane of polarized light. These basic structures of rhabdoms have been seen also in crustacean eyes. But exceptionally in a crab eye, the microvilli from a cross retinular cell are arranged in two directions at right angles to one another. This means that the cell can't be an analyser for polarized light. The very distal location of the cell in the longitudinal retinular layer indicates however that it may function as a detector at low light intensities.

THE GROWTH OF THE FIRST VISUAL PROJECTION OF *CALLIPHORA*

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The morphogenesis of the complex retina-lamina connections of the short retinula axons of the optic lobe of the blowfly *Calliphora* is of particular interest because each axon terminates in one predictable location out of very many other apparently identical ones. In the third instar larva these axons grow between the eye imaginal disc through the optic stalk and into the larval hemisphere, where they terminate in the presumptive lamina. There is a sequence of cell divisions in both the eye disc, forming retinula cells, and the hemisphere, forming lamina monopolar neurones, and another sequence of axon growth between the two regions. The inter- and intra-ommatidial sequences of axon growth as reconstructed from serial EM are reported and, by a study of the synchronisation of these patterns, a rather exact description may be made of the minimal information which axons of each class need in order to establish their correct connections.

STRUCTURE AND FUNCTION OF EYES OF NOCTURNAL SCARABAEID BEETLES

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Migration of screening pigment causes eye-glow in the dark-adapted state which can only be found at night. If the dark-adapted animal is exposed to light for only 5 seconds, the eye-glow disappears within a few minutes and the eye becomes light-adapted.

Optomotor experiments show that light-adapted animals are able to resolve regular stripes of 15° repeat period. They fail to resolve any stripes at a light intensity of 8 Lux. Dark-adapted beetles don't respond to moving stripes narrower than 25°, but are able to respond to wide stripes even at a light intensity of 0.3 Lux.

Measurements of refractive indices of the dioptric apparatus allow reconstruction of light paths by ray-tracing. As revealed by microspectrophotometry the cornea absorbs short wavelengths more completely than long ones. Absorbtion in the cone is negligible.

From ray-tracing, eye-shine experiments and optomotor reactions an acceptance angle of about 25° in the dark-adapted eye can be concluded.

VISUAL PIGMENTS OF THE LARVAL MOSQUITO *AEDES AEGYPTI*

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The visual pigments of the lateral larval ocelli (homologues of the ommatidia of the compound eye) of the mosquito were measured by microspectrophotometry. The ocelli contain a typical arthropod rhodopsin with λ max at 515 nm. Mosquito rhodopsin "bleaches" to a stable photoequilibrium with metarhodopsin (λ max 480 nm). When living larvae are flashed with light to establish such a photoequilibrium, it remains stable in subsequent darkness for more than an hour. Neither hydrolysis of metarhodopsin nor regeneration of rhodopsin occurs in darkness. Nevertheless, dark adaptation of the electroretinogram proceeds rapidly, indicating that dark adaptation is largely "neural" adaptation. Although rhodopsin regeneration does not occur in darkness, photoregeneration occurs and may be an important mechanism of rhodopsin renewal in the insect photoreceptor.

INVESTIGATION OF VISUAL PROPERTIES IN ANTS

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The ERG was used for measurements of the fundamental parameters of the compound eye of the worker *Lasius niger* and *Formica cunicularia*. The ERG of both species is monophasic corneo-negative. The critical fusion frequency is about 75-80 flashes per sec. The dark adaptation of *F. cunicularia* lasts 20-25 min. During this period the threshold sensitivity increases 50-70 times. The curve of the equal spectral respones of the dark adapted eye of *F. cunicularia* has a maximum at about 510 nm but that of *L. niger* is at 500 nm. The relative sensitivity for UV with λ = 365 nm reaches 20% of maximum in *F. cunicularia* but less than 5% in *L. niger*. Selective colour adaptation shifts the maximum of the spectral curve. By means of flickering colorimetry, two types of receptors were found in *F. cunicularia:* one with λ max ≃ 470 nm and the other with λ max ≃ 540 nm. The two last results are interpreted as indicating the existence of two different visual pigments in the retina of ants.

N THE ORIGIN AND MODIFICATION OF THE RECEPTOR POTENTIAL OF THE LATERAL EYE OF *LIMULU*

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Retinular cells in excised lateral eyes of *Limulus* were impaled. Conventional recording and analytical techniques were used. A few experiments showed that the slope of the leading component (C1) of the receptor potential increased upon driving the pipette deeper into the cell. This phenomenon was confirmed using a differentiating circuit.

Sufficient depolarization of retinular cells causes polarity reversal of the receptor potential but C1 and the plateau component (C3) reverse at a higher potential than the transient component (C2). Depletion of Na^+ in the bathing medium affects C2 more rapidly than C1. Cyclic AMP in the bathing medium suppresses C1 more than C2 and $MnCl_2$ suppresses C2 more than C1.

These observations and those of other investigators indicate that the membrane mechanisms producing C1 and C2 are different and suggest that C1 and perhaps C3 originate deep within the retinular cell in the region of the rhabdomeric membrane.

EVOLUTION OF MIGRATION AND DISPERSAL PATTERNS

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Systems of migration and dispersal are the product of two variables: rate and pattern of voluntary displacement. Voluntary displacement can be contrasted with enforced displacement. Rate of voluntary displacement evolves according to the characteristics of the habitat to which the species is adapted. Pattern of voluntary displacement evolves according to the interaction of rate of voluntary displacement and seasonal incidence of the species with certain geographical gradients, e.g. temperature in temperate butterflies, abundance of vegetation in the Desert Locust. Rate of voluntary displacement may vary during the ontogeny of the adult insect but the öogenesis - flight syndrome of Johnson can hardly be claimed as a characteristic of insect migration. Some insects have a high rate of voluntary displacement but have a pattern which does not include a peak geographical flight direction. 'Dispersal' seems the term best suited to describe this system. Other insects have a pattern of voluntary displacement which includes a peak geographical flight direction. 'Migration' seems the term best suited to describe this system.

THE COMPONENTS OF INSECT MOVEMENT - AN APPROACH TO SIMULATION

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The complexity inherent in the study of movement of insects makes simulation methods instructive and a valuable tool. Components general to all types of ecological movement (from foraging to the zoogeographical spread of a species) can, and indeed must, be identified in this approach.

Any movement event can be divided temporally into three, departure, transit and arrival. At departure significant components include fuel 'capacity', flight ability, social facilitation and take-off stimuli. In transit major components are flight speed and directionality, fuel reserves and rate of utilization and in-flight mortality. Arrival is divisible into detection, goal-finding and establishment. These components may be described as functions of various aspects of the biology of the insect, the structure of the habitat(s) in which the movement occurs, other organisms present in these habitats and the particular and synoptic climate before, during and after the event.

Movements can be conveniently stratified into colonization, migration, dispersal and interspersal and these levels may be studied using the common framework provided by a generalized set of components. Such a standard approach may allow comparisons and general conclusions about the nature of insect movement.

MEAN DISPERSAL DISTANCES ATTAINED BY INSECT POPULATIONS OF DIFFERENT DENSITIES

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It may be expected that longer distances would be travelled by some insects in a large population than in a smaller one, but very little work is known on this phase of population dynamics. An understanding of this factor is important in taxonomical studies, parasite release activities, chemical control, and other entomological enterprises.

Under controlled laboratory conditions experiments were done in which restraints were imposed on the movement of the green peach aphid, sweet potato weevil, Caribbean fruit fly, and tobacco budworm. Dispersal ranges were provided for movements of the members of different populations released at an origin. There were four replications of each population density and statistical methods were used to evaluate the results and show how mean dispersal distances were affected by different densities. Regression of population density on distance showed that as the population density increased the mean distance of dispersal increased.

DISPERSAL BY FLIGHT OF SOME GRASSLAND LEAFHOPPERS

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Between 50 to 60 species of grassland leafhoppers are collected annually in the aerial suction traps at the Imperial College Field Station, Silwood Park. Usually half of the catch is composed of two species only, *Macrosteles sexnotatus* (Cicadellidae) and *Javesella pellucida* (Delphacidae). This is considered to be related to their flight performance, rather than abundance.

The patterns of dispersal by flight have been examined in several species and related to voltinism and seasonal abundance.

Many species show wing polymorphism and some exhibit extreme brachyptery and macroptery. In a second set of species ability to fly is linked with the ratio of the length of the fore to hind wing. In a third set, all individuals of a species are macropterous and capable of flight, yet some have extra long wings. In the delphacid *Stenocranus minutus*, the extra-long winged individuals have more extensive black pigmentation and are the only members of the field populations that have been caught in aerial traps.

THE MIGRATION OF CAVE ARTHROPODS ACROSS THE NULLARBOR PLAIN, SOUTHERN AUSTRALIA

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The Nullarbor Plain is a low plateau of Tertiary limestone covering an area of 194,175 km^2 in southern Australia. It has a semi-arid climate and supports a stunted vegetation. Ninety-five species of arthropods have been recorded from the numerous caves, and many of these species are widely distributed across the plain. Two possible explanations for their distribution are discussed. While cave arthropods are confined to the cool, moist cave environment during the day, they have been observed at night in cave entrances, in dolines and on the surface of the plain. Cave "breathing", similarity in cave and epigean climate at night, strong winds, occasional heavy rain and numerous animal burrows all contribute towards favourable conditions for surface migration. Subterranean migration may occur through the widespread zone of small interconnecting cavities in the Nullarbor Limestone, but this has not yet been confirmed.

THE EVOLUTION OF SOCIAL BEHAVIOUR IN ANTS

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Ant societies provide exceptionally favourable opportunities for research into evolution of social behaviour. They form a definitely homogeneous group which is nevertheless very diversified; moreover, a detailed study has been made of the patterns of relationship in this group, and the mechanisms which condition these relations are beginning to be well known.

Thus ant societies offer a remarkably clear model of evolution of behaviour. This has been borne out by recent results: particularly with colony-founding in *Manica*, ants belonging to the higher sub-family Myrmicinae, which in this respect, behave like the very archaic Australian Myrmeciinae.

Likewise, study of social parasitism in ants reveals that the same evolutionary phenomena have been repeated in different lines, as a convergence phenomenon, often allowing the necessary cross-comparisons and validations, and finally phylogenetic reconstructions. This is also the case for relations between the brood and adults.

RELATION OF PROVISION WEIGHTS TO SEX OF PROGENY OF *MEGACHILE ROTUNDATA* (HYMENOPTERA: MEGACHILIDAE)

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Nest weight changes during nest construction and provisioning were recorded with a specially constructed weighing device. The nesting female provides about 10 mg more provisions for female progeny than for males. Leaf pieces weigh about 4 mg and provision loads about 5 mg with maximum loads of 10 mg recorded for a 38 mg bee. Bees collect 2 or 3 times their weight of provisions for each cell. Each nectar-pollen collecting trip takes about 15 minutes and the bee visits about 15 flowers per minute. Nectar collecting trips take less than 5 minutes but the nectar load weighs as much as the nectar-pollen loads, indicating that the bee visits fewer flowers but obtains more nectar from each flower than when collecting pollen. The data suggest that the nesting female provides more provisions in cells destined for female progeny than in cells for males.

FOREIGN NEST VISITING OF *PARAGYMNOMERUS SPIRICORNIS* SPINOLA (HYM.: EUMENIDAE)

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The author reported previously that *Paragymnomerus spiricornis* which lives in a solitary manner but nests in groups, intruded in nests of other wasps of the same species. Recently the author marked 109 nests with little flags and dots of paint, simultaneously painting combinations of signs of different colours on the notum of 53 wasps. By this marking technique it was shown that 16 wasps intruded in 2 to 4 foreign nests each during the course of their activities. Two wasps, after their activity in the foreign nest, returned to their original nests some days later. In 4 nests 2 wasps sojourned simultaneously; in one nest a wasp was found together with a *Sceliphron* for a short time, and one with an *Osmia* for a day. The wasps present in the same nest usually fought and tried to expel each other. These facts call for further study of the observed phenomena, as well as a revision of the conclusions drawn from earlier ethological observations.

PATTERN OF NEST BUILDING IN TWO SOCIAL WASPS

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Observations were made on the nest building of *Ropalidia variegata* and *Vespa cincta* at Calcutta. *Ropalidia* was active all year round, but all adults of *Vespa* perished during winter. The foundation cell of *Ropalidia* nest has the single pedicel, further cells being attached downward in two or more rows. The number of rows of cells varied significantly with nests founded on different host plants. Only the founding female builds the nest. In *Vespa* numerous workers build the nest. A broad foundation is made on a strong palm leaf and horizontal combs are built one below the other with central connections. Combs are encased by a thick shell. Enlargement of cavity is effected by removing layers from inner to outer surface of shell wall. Different kinds of pulp are used for building comb and shell. Two doors were provided on the shell, one mainly for incoming and the other for outgoing adults.

OVIPOSITION BEHAVIOUR IN VERMILEONINAE (DIPTERA: BRACHYCERA: RHAGIONIDAE)

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All the six Mediterranean or Canarian species studied dig a pit in dusty substrates with the simultaneously backward moved middle legs (phase 1) and lay an egg in the pit. The egg is covered and the pit refilled (phases 2-3) by middle (*Lampromyia pallida* Macquart) or both fore and middle legs (other 5 species).

Species differences in (a) the length of phase 1, (b) the length of phases 1 and 2, and (c) the use of different pairs of legs and abdominal movements during the different phases are described.

The influence of temperature, light and particle size in the substrate, especially on length of phase 1, is described for two Canarian species. Their oviposition behaviour is illustrated in cinematographic pictures. These films also show larval and pupal behaviour and feeding and mating behaviour of adults.

THE ADULT HABITS OF *DOLANIA AMERICANA* (BEHNINGIIDAE: EPHEMEROPTERA)

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Dolania americana Edmunds *et al.* is known from various localities in the coastal area of the southeastern United States and the nymphs inhabit clean shifting sand in rivers. The habits of the nymphs are similar to those of *Behningia lestagei* Motas & Bogoescu in Europe. Except for a short egg stage, nymphs are present all year and emerge in late April. Male subimagos emerge 1½ hours before sunrise; subimagos soon molt to imagos over the water and then patrol the river in a slow pattern. Female subimagos emerge 1 hour before sunrise and then molt to imagos. Mating occurs in a fast straight mating pattern with the female superior. Females lay eggs individually and die on the water before sunrise or at sunrise, but males continue to patrol the river slowly until death at full sunlight.

UTILIZATION OF SPATIAL DISTRIBUTION OF EGGS FOR STUDYING THE MOVEMENTS OF *DROSOPHILA* FEMALES

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In laboratory experiments, it is always very tedious to observe the activity of insects in order to determine their distribution and movements. Observations lasting for a few minutes are not usually representative enough but for those lasting several hours some automatic recording system is necessary. But, for a small insect such as *Drosophila* a recording apparatus would be very difficult to work out. It has been possible to overcome this difficulty by using the spatial distribution of the laid eggs as a "memory" of the female movement and distribution during periods of 24 hours.

With such techniques, it was possible to measure the repellency of live yeast and the modification of the female behavior with ageing. The very high sensitivity of *Drosophila* females to small air movements was demonstrated. Finally, the response of the females to gravity was also analysed.

It is hoped that these methods will be convenient for studying the effects of various kinds of attractants and repellents.

RADIOPERCEPTIBILITY OF ADULTS OF *SITOPHILUS ZEAMAIS* MOTS.

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The perception of gamma radiation by a few species of organisms has been demonstrated. We have carried out experiments to determine whether or not *Sitophilus zeamais* Mots. shows any behavioural response to radiation.

Tubes containing insects were placed at a position radial to the gamma source and the locomotion of the insects was recorded in the presence and absence of radiation. Observations were made with the tubes at different distances from the source and it was found that the insects which experienced gamma radiation moved away from the source.

This effect may possibly be correlated with the Cerenkov effect, acting directly on the visual organs of the insects.

THE INTEGRATIVE PROPERTIES OF SECOND-ORDER VISUAL UNITS IN THE DRAGONFLY

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Insect compound eyes, with their ordered system of parallel inputs constitute a favourable system for the study of visual integration. Stable intracellular recordings have been obtained from monopolar cell axons (second order) leaving the lamina (first optic neuropile). Their response to light is a graded hyperpolarisation of up to 20 mV and their field of view corresponds to that of a single ommatidium. The possibility of interactions between monopolar cells is explored and the relevance of such interactions to the abstraction of visual information discussed.

CELL MOVEMENT ON LIGHT/DARK ADAPTATION IN COMPOUND EYES

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Insects belonging to a number of different orders, Diptera, Hemiptera, Lepidoptera, Coleoptera, Neuroptera and Megaloptera exhibit extensive cell movements on light/dark adaptation. Ultrastructural examination of a number of insect compound eyes shows that microtubules are present in many of the cell types that move and that these microtubules are highly oriented in the direction of movement.

In the retina of the compound eye of the giant water bug, *Lethocerus*, the effects of these cell movements have been studied by intracellular recordings. The results show that the sensitivity of retinal units decreases by 3 Log units on light adaptation and that the acceptance angle decreases from 9.0° to 3.5°. These physiological changes are correlated with the anatomical changes.

PHYSIOLOGICAL EFFECT OF CYCLIC AMP IN *LIMULUS* PHOTORECEPTOR

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Cyclic AMP level in vertebrate rod photoreceptor organelles is regulated by illumination *in vitro*. Production continues in digitonin solution, but regulation is lost with a time course paralleling rod disk disruption. In the cone and rhabdomeres where the photoreceptor organelle is a continuous infolding, rather than intact disks, cyclic AMP is produced *in vitro*, but not regulated by illumination, just as with the rod digitonin preparation. In physiological experiments to be discussed, methyl xanthines and cyclic AMP cause depolarization of the *Limulus* photoreceptor cell.

EVIDENCE FOR COLOUR RECEPTORS IN THE HYMENOPTERAN EYE OBTAINED FROM SELECTIVE ADAPTATION EXPERIMENTS

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Colour receptors in Hymenoptera can be analysed by means of the electroretinogram, if one compares the spectral sensitivity in the dark with that obtained doing chromatic adaptation with ultraviolet, blue and yellow lights. Three different receptors can be demonstrated (λ_{max} = 375 nm, λ_{max} = 450 nm and λ_{max} = 520 nm).

In the ant *Formica polyctena* the colour receptors can also be demonstrated in electronmicrographs: the retinula cells contain, in their distal portion, pigment granules which congregate very close to the rhabdom following illumination. After adaptation with ultraviolet, the two small retinula cells, number 1 and 5, display pigment migration; the remaining cells adapt selectively to yellow light.

The significance of both the electrophysiological and ultrastructural demonstration of colour receptors with respect to the functional organisation of the Hymenopteran eye is discussed.

THE ROLE OF THE DORSAL OCELLUS IN INSECT VISION

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A study of the fine structure of a number of insect ocelli from representative orders has shown that the first order synaptic region is complex, several types of afferent and efferent second order fibres being present. The organization of this region differs in the ocelli examined suggesting that their role may vary between orders. Electrophysiological studies have shown that interaction occurs between ocellar inputs and between ocellar and compound eye inputs at more than one level in the central nervous sytem.

The importance of considering possible ocellar contributions when conducting behavioural and electrophysiological studies based upon the compound eye is discussed.

OPTOMOTOR RESPONSE STUDIES WITH SPECTRAL LIGHTS - BEHAVIOURAL EVALUATION AND SINGLE UNIT RECORDING IN HONEYBEES

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Motion detecting interneurones exhibiting directional specificity have been found in the optic lobe of the honeybee. Extracellular recording during "optomotor" experiments indicated that these interneurones belong to the optomotor system. In order to determine whether these interneurones also transfer *colour* information, a rotating striped pattern consisting of pairs of spectral colours (ultraviolet to red) was used. Colour matching experiments showed, that for an exactly definable intensity ratio between the two colours, the neuronal activity during pattern movement was indistinguishable from spontaneous levels. These results suggest that the bee's optomotor system is independent of its "colour system". The author's earlier behavioural experiments with flies suggested the same hypothesis. Behavioural optomotor studies with *bees* should provide a conclusive test. Those experiments already performed support the hypothesis.

Extremely precise spectral sensitivity curves, derived from the colour matching experiments, indicate that the green receptor dominates the optomotor system of the honeybee. The extent to which other receptors are involved is under investigation.

OPTOKINETIC RESPONSES IN LOCUST

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Previous studies of optokinetic responses in arthropods have employed small windows to limit the field of rotating stripes visible. Painting the eye allows a more accurate control of the number of facets actually being used to initiate a response. Using this technique it has been found in locusts that, as the number of facets decreases, the ability of the animal to respond in the direction of motion diminishes, reaching random at 80-300 facets for narrow stripe widths. By exposing rectangles of facets perpendicular to, or in the direction of motion, vertical and horizontal interaction between facets can be deduced. The interaction perpendicular to direction of motion appears to be simple summation. However, in the direction of motion the interaction is complex spreading over a large number of facets. Responses to single edges and varying numbers of stripes give necessary input parameters and lead to formation of a model for perception of direction of movement.

FORM-DISCRIMINATION AND SPATIAL ACUITY IN INSECT VISION

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Data obtained from single-unit recording in optic lobe neuropile in locusts have led to the definition of eight categories of units which perform unique operations on properties of the visual object. These categories may be grouped into three classes: (1) Vector units which respond maximally to contrasting edges and/or spots moving in a preferred direction at an optimum speed. These units obey the Nyquist sampling theorem for spatial resolution. They project into the VNC and cervical nerves. (2) Moving-spot sensors (e.g., multi-modals) exhibiting anomalous spatial resolution beyond the Nyquist limit. They discriminate against moving edges and are not directionally-sensitive. (3) Units sensing light and dark which have no form-sensitivity.

Neural models of visual processing are presented which mimic the form-discrimination and movement sensitivity described for classes (1) and (2), and which account for anomalous resolution in class (2).

MONOCULAR AND BINOCULAR VISION IN THE LANDING REACTION OF *MUSCA DOMESTICA*

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The landing reaction does not require binocular vision. Stimulation in a single visual field of a monocular fly produces a landing reaction in both ipsi- and contralateral legs. Stimulation in a superimposed visual field, however, produces a reaction only in the ipsilateral legs.

A fly in a fixed spatial position may react to a lateral displacement in its visual field with a landing reaction.

The threshold for landing due to an expansion in the visual field (landing stimulus) is lower than the threshold for landing due to lateral displacement.

If the fly is allowed to turn itself, however, it produces a complex behaviour that includes optomotor and landing reactions in a typical time pattern dependent on the stimulus presented. In such a case, the landing reaction may not always correspond to a landing stimulus but may be interpreted as a response to an escape stimulus subsequent to a natural response.

PHYSIOLOGICAL AND ECOLOGICAL INTEGRATION OF FLIGHT AND REPRODUCTION IN MIGRANT INSECTS

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Flight and reproduction interact in an adaptive syndrome in migrant insects. An example occurs in African *Dysdercus* spp. (Heteroptera) which reproduce and histolyse wing muscles in the presence of food, but delay reproduction and migrate when starved. Although most extensively studied in Hemiptera, examples of the syndrome are present in other orders as well. Temporal adjustments in flight and reproduction have ecological consequences in terms of colonization potential. Early reproduction leads to rapid population increase, a good colonization strategy, but escape from unfavorable conditions requires reproductive delays. Selection experiments in *Oncopeltus fasciatus* (Heteroptera) have elucidated the optimization of choices between alternatives in a photoperiodically modifiable system. In any event, a migrant colonizer has its reproductive life ahead of it when it invades an empty universe. In terms of migration theory, studies of the reproduction-flight syndrome indicate that the Johnson-Kennedy Southwood model needs some updating, but that its basic tenets are sound.

AN EXPERIMENTAL ANALYSIS OF THE STRATEGIES OF DISPERSAL BEHAVIOUR IN TWO MILKWEED BUGS, *ONCOPELTUS FASCIATUS* AND *LYGAEUS KALMII* (HETEROPTERA: LYGAEIDAE)

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Oncopeltus fasciatus and *Lygaeus kalmii* occur together in the northern United States in mixed stands of milkweed. *L. kalmii* is a permanent resident, whereas *O. fasciatus* colonizes each summer from tropical and sub-tropical regions. Since most milkweeds are early successional species which are eliminated as succession proceeds, both bugs must frequently locate new stands of the host. *O. fasciatus* effectively scans all available habitats by migrating northward each spring. *L. kalmii* undertakes a dispersal flight in the early spring if conditions indicate habitat deterioration. Migration in *O. fasciatus* is dependent on a photoperiodically induced reproductive diapause controlled by corpus allatum activity while dispersal in *L. kalmii* is governed by such proximal factors as temperature, food, crowding, and the occurrence of mates and is not under control of the corpus allatum. In both species the proportion of a population committed to flight under optimal conditions for dispersal is genetically determined and is related to the distribution and persistence of habitats.

AN EXPERIMENTAL ANALYSIS OF THE PHYSIOLOGICAL CONTROL OF FLIGHT AND REPRODUCTION IN *ONCOPELTUS FASCIATUS* (HETEROPTERA: LYGAEIDAE)

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The complex and highly adaptive temporal segregation of "vegetative" activities such as oviposition, mating and feeding from flight behaviour in the migrant insect, *Oncopeltus fasciatus*, suggested a coordinated control of reproduction and flight in this insect. To investigate this possibility, the level of juvenile hormone activity was experimentally increased in young *O. fasciatus* by topical application of a synthetic JH analogue. Significantly greater proportions of males in experimental populations made long flights than did controls. In both males and females synthetic hormone treatments accelerated the onset of reproduction. Since long flight in female *O. fasciatus* is inhibited by the onset of oviposition, the effects of applied hormone on egg development resulted in a significant decrease in flight activity in treated females. Ovariectomized females, however, responded to hormone applications with significantly greater numbers of long flights. Pseudo-allatectomy by starvation resulted in a lower proportion of long flights among treated individuals. Flight activity could be increased in such experimental groups by hormone replacement therapy (JH mimic application or allatal implantation), indicating a positive role by the corpus allatum of this species in the timing of migration and the production of a reproductively mature migrant colonizer.

ANALYSIS OF THE PHYSIOLOGICAL BASES OF THE MIGRATION BEHAVIOUR OF *MELOLONTHA MELOLONTHA* L. (COLEOPT.: SCARABIDAE)

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The behaviour of adult *Melolontha melolontha* females is characterized by a reversing of the flight direction of the egg-laying female. The role of the corpora allata has been demonstrated by transplantations. Implantation of the corpora allata of egg-laying females induced a reversal of flight direction and stopped oogenesis in young females.

RADAR STUDIES OF THE FLIGHT ACTIVITY AND AERIAL TRANSPORTATION OF INSECTS

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Inexpensive 3 cm radars have monitored insect dispersion in the Sahara, New South Wales and the Sudan, financed by COPR, CSIRO, and CIBA-Geigy respectively. Individual moths and grasshoppers were detected to 1.7 and 2.6 km and insect concentrations to 70 km. Only insects with body length exceeding 8 mm are considered.

The characteristics of undisturbed nocturnal dispersion were: peak take-off occurred 55 min (40-70) after sunset, the insects climbed at 0.3 m/s (0.6 max) to a median height of 400 m and a temperature-limited ceiling of 1.5 km (1.0-1.8), flew for 3 hr (1-12) at a ground speed of 30 km/hr (10-80), travelling 90 km (30-500) per night, generally in a low level jet stream. Height distributions were not generally logarithmic. The insects were frequently orientated, usually down-wind. Species and sex were often identified by wing-beat frequency (primarily Acrididae and Noctuidae).

Wind convergence frequently disturbed the dispersion, causing strong concentrations (horizontal layers, wind-shift lines, Inter-Tropical Front, storm outflows, Bénard convection cells), with densities up to $10^{-2}m^{-3}$ and airborne populations up to 3.10^4/hectare. Evidence was obtained in the Sudan Gezira that the spatial and temporal extent of pest outbreaks might be determined by such features, suggesting new approaches to pest control.

MIGRATION AND DISPERSAL IN THE AUSTRALIAN PLAGUE LOCUST

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The directions of the main population displacements in *Chortoicetes* are determined by low level wind flow. Recent radar studies have confirmed that long range displacement occurs most frequently amongst individuals which take off just after sunset and fly downwind for up to 15 hours. Long range migration by high flying swarms occurs infrequently and is associated with warm northerly winds ahead of fronts approaching from the south-west. During the warmer months the vector mean wind flow over the interior of eastern Australia backs diurnally being easterly at night. Night flying adults produced in the eastern outbreak areas therefore migrate westward towards the interior which although more arid receives its peak rainfall in the summer. Providing the rains in the interior do not fail a high proportion of the migrants locate those areas in which rain has fallen and which are suitable for successful reproduction. Swarms produced in such areas migrate southwards intermittently and after 1-3 generations their progeny, which may be more or less numerous depending on intervening breeding success, reach the cultivated areas of south-east Australia where they may cause considerable economic loss.

VISUAL NAVIGATION IN *DROSOPHILA*

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The 1400 visual elements in the compound eye of the *Drosophila* subtend about 86% of the environment and the fly reacts on motion in almost any part of the visual field. The integration of the signals from motion detectors in different eye regions is remarkably simple and reflects the apparent inability of *Drosophila* to focus attention on events in a particular part of the visual field. Open loop recordings of the optomotor reactions have revealed the existence of at least two independent motion detecting systems. One of the systems responds to the horizontal components of motion, whereas the other is sensitive to the vertical components of motion. The information of the horizontal system is conveyed to the muscular system of the legs and the wings, where it controls the *difference* between the locomotor forces on either side. The corresponding torque reaction enables the freely moving insect to counteract involuntary deviations from a straight course in a stationary environment. The information of the vertical system is exclusively conveyed to the flight system where it controls the *sum* of the locomotor forces on either side. The thrust reaction is obviously used to maintain a given level of flight. Present efforts are also concentrating on the search for genetically determined modifications of the optomotor control system.

LUMINOUS CHARACTERISTICS OF THE STIMULI ELICITING LANDING REACTION OF *MUSCA DOMESTICA* (DIPTERA)

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The housefly shows a landing reaction to both an expanding visual stimulus or a decrement of the environmental light level. The quantitative relation between the separate dependence of landing reaction on expansion and on light level decrement is analysed.

The housefly shows, at different light levels, different reactivities to expanding stimuli that can be correlated with the two Diptera visual systems and that could be explained by the existence of an alerting mechanism weighting stimuli for landing reaction at low illumination levels.

Testing the fly with expanding patterns differing in the percentage of the total area covered by black, it was shown that the housefly landing reaction, as with the optomotor reaction, depends on the square of the perceived stimulating pattern contrast and on the sum of the absolute values of Fourier coefficients of the stimulating pattern. Also the housefly is phase blind with respect to the landing reaction.

THE REGULATION OF FOOD INTAKE BY ACRIDIDS

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The quantity of food ingested at one feed by an acridid depends on a balance between stimulatory and inhibitory inputs. Experiments in which nerves from the foregut wall were cut show that stretch receptors at the front of the foregut are of prime importance in limiting meal size. Complete distension only occurs if the food is highly acceptable. Acceptance involves positive stimulation by the waxes on the surface of the leaf. Other waxes may contain an inhibitory component and feeding is enhanced by their removal.

After lengthy food deprivation much of this information is ignored and selection is then based on the internal components of the food.

Distension of the foregut, by feeding or artificial means, results in the release of a hormone from the corpora cardiaca which apparently has the effect of shutting off some of the peripheral sensilla, a factor which may also contribute to the cessation of feeding.

CENTRAL CONTROL OF FEEDING IN DIAPAUSING ADULT *PHORMIA REGINA* (MEIG.) (DIPTERA: CALLIPHORIDAE)

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The idea that diapause represents not only extrinsic control over growth, differentiation, and reproduction, but also behaviour must be experimentally investigated. The alternate patterns of behaviour that are typical of insects with adult diapause provide several parameters to measure. The black blowfly serves an excellent model for comparing the feeding behaviour of diapausing and non-diapausing adults because of the extensive amount of literature already available concerned with feeding of the non-diapausing adult.

Diapausing *Phormia* fail to mate, cease feeding, and become photonegative. Behavioural determination of median tarsal acceptance thresholds showed that diapausing flies had a significantly higher threshold than non-diapausing adults of the same age. Determination of the amount of sucrose a fly would imbibe for one uninterrupted drink showed that diapausing flies imbibed significantly less and drank for a significantly shorter period of time. When diapausing flies were removed from diapausing conditions, however, the tarsal thresholds, amount of fluid imbibed, and duration of sucking approximated that of non-diapausing flies. This demonstrated that some form of inhibition was removed while under non-diapausing conditions. Electrical recordings from the labellar hairs showed that there was no significant difference between the frequencies (impulses/sec.) of diapausing and non-diapausing flies. Failure to show any differences at the receptor level suggests that the elevation of the tarsal threshold in diapausing flies is due to central inhibition and not peripheral inhibition.

AN ANALYSIS OF DIRECTION FINDING IN MALE MOSQUITOES

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The flight patterns of male *Aedes aegypti* were recorded with a flash-synchronized cine camera as they were attracted to sounds. When sine waves with frequencies centred on 500 Hz and sound pressure levels near 70 db at 2.5 cm from a small earphone were used, most of the mosquitoes flew directly toward the sound. In some experiments males flew directly away from the sound before turning and flying toward it. These findings are related to ultrastructural and electrophysiological investigations of Johnston's organ.

When the position of the male is fixed, the phase relationships and amplitudes of the potentials recorded simultaneously in both Johnston's organs vary with the position of the earphone. These potentials provide sufficient information to account for the observed flight behaviour without invoking the widely accepted "Klirrfaktor" hypothesis.

TIME LINKED PROCESS OF LEARNING AND FORGETTING IN HONEYBEES

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If bees are trained to learn a scent at a fixed time of the day, they link this information with the hour of the day the training took place. The next day they remember the scent precisely 24 hours after the training time.

The same corresponding memory rhythm will be found if they are trained twice, three, five or nine times with intervals of respectively six, three, two hours or 45 minutes.

Bees are able to distinguish between two points of time that are separated by 20 minutes only.

If bees learn two different scents each at a different time of the day, they remember this information exactly 24 hours after the time of training.

Bees also learn colours in a time linked process and remember them in a 24 hour cycle.

Time linking proves, therefore, to be a fundamental law in the learning and remembering process of bees.

TIME-DEPENDENCE OF LEARNING PERFORMANCE IN THE HONEY-BEE

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Bees require only a few rewards to learn a colour stimulus (over 90% correct responses); three weeks later, the training colour is still remembered with the same efficiency. After a *single* presentation of the training colour only 70% correct responses are made, and the colour is forgotten within 6-8 days. With different durations of reward presentation (more or less than 2 sec.) together with a special testing method, we could demonstrate that the stimulus is first stored for a few minutes and then for a longer time. Whether the stimulus is stored for the shorter or longer time depends on the duration of the reward; there is no dependence on such factors as concentration, flow velocity, etc. of the reward solution.

LEARNING IN PRAYING MANTIS - A BEHAVIOURAL AND BIOCHEMICAL APPROACH

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Adult female mantis (*Stagmatoptera biocellata*) were trained not to strike at a moving object. A special experimental device allowed us to record automatically the performance of 12 animals simultaneously. The decrement in number of attacks was interpreted as the expression of a learning process. Retention proved to be as long as 12 days and a long lasting change in behaviour was shown with only an initial block of 20 trials. Influence of both the intersession and the intertrial intervals on learning was analysed. Results showed that a long lasting change in performance could take place with a small number of initial trials provided that intervals were interspersed between trials. Autoradiographic and biochemical methods were used to test the hypothesis that learning not to attack was correlated with a change in the protein content in the protocerebrum. Curves of C14-leucine incorporation in the protocerebrum were plotted against time. Changes due to activity and those due to learning were distinguished.

CORRELATION OF AMOUNT OF VISUAL INFORMATION, INTERTRIAL INTERVAL AND HABITUATION TIME OF DEIMATIC RESPONSE IN MANTIDS

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The sighting of moving birds releases in mantids a defensive behaviour: The Deimatic Reaction. This reaction was also elicited with cinematographic projections of moving birds, provided the film speed was > 100 frames/second. A special high speed movie projector equipment, which permits the discontinuous or continuous projection of films was developed. To study the correlation of the amount of information, intertrial interval and habituation time of deimatic reaction, several groups of the mantid *Stagmatoptera biocellata* were visually stimulated. The trials consisted of films showing birds moving with "varied" and "monotonous" activity patterns. These were shown with and without intertrial intervals in daily sessions until habituation occurred. Significant differences were found in habituation time, which show that intertrial intervals are required to process information, especially as the amount of information increases.

THE ATTRACTION OF NEWLY-HATCHED CODLING MOTH (*LASPEYRESIA POMONELLA*) LARVAE TO THE APPLE HYDROCARBON α-FARNESENE

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In laboratory tests volatile components of both the skin of the apple cultivar "Sturmer Pippin" and a chloroform extract of the natural coating of the fruit were highly attractive to newly-hatched codling moth larvae. Column chromatography of the chloroform extract yielded a series of fractions of which only that containing polyunsaturated hydrocarbons was active in the bioassay. The predominant component of this fraction was isolated and proved to be a potent attractant for young larvae. It was identified by gas-liquid chromatography as the sesquiterpene α-farnesene.

Larvae responded equally to synthetic and natural α-farnesene and the behaviour of the insects in an odour gradient was manifest as a klinotaxis. In a closed arena larvae were attracted from a distance of 6.5 cm. There was, however, a differential response to various of the stereo-isomers of farnesene.

CONTROL AND SIMULATION OF HOST SELECTION BEHAVIOUR OF CERTAIN PHYTOPHAGOUS INSECTS

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This paper examines the ways in which different factors interact to control the selection of host plants by insects. These factors are of three main types: (1) *Sensory stimuli* from plants and their vicinity; (2) *Physiological state of the insects* which depends on such factors as starvation, desiccation, moulting, reproductive state, which determine the insects' responses to stimuli; (3) *Certain environmental conditions* such as temperature, humidity, wind, which play a part in determining the insects' physiological state.

The insects, when out of range of stimuli, wander at random, being starved and desiccated at a rate which depends upon such factors as temperature, humidity and wind. Upon receiving stimulation the insects show positive or negative responses (orientation, feeding or oviposition) depending upon the type of stimulus and their physiological state. If these responses result in ingestion of water of food, or in oviposition the physiological state changes and modifies the insects' subsequent responses. The nature and range of stimuli from sources located at different places determine the successive responses and physiological states of the insects which result in the success or failure of their establishment on different plants.

A computer-based model simulating these interactions of factors controlling the host selection behaviour of the insects has been devised.

CHEMICAL REGULATION OF FEEDING BEHAVIOR IN *LEPTINOTARSA* BEETLES

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The genus *Leptinotarsa* (Chrysomelidae) is indigenous to America and many species feed exclusively on Solanaceae, especially *Solanum*. Food specificity of seven species has been investigated to elucidate the modes of chemical influences on feeding behavior. At least four types of plant chemicals are responsible for initiation and regulation of feeding responses. These are sign stimulants (host specific chemicals from Solanaceae), feeding stimulants (sugars, amino acids, phospholipids), feeding co-factors (potassium and other inorganic salts) and deterrents (alkaloids from Solanaceae). These chemicals act singly or jointly to produce stimulative or inhibitory effects on feeding in a manner peculiar to each species. Different gustatory receptors of the mouthpart are involved in the discrimination of these plant chemicals. The nature of oligophagy in *Leptinotarsa* species is determined by their sensitivity and tolerance toward the various types of plant chemicals. Those species which respond to the largest number of feeding stimulants and co-factors and at the same time exhibit the greatest tolerance to deterrents are correspondingly more diverse in their host range.

HOST PLANT LOCATION AND SELECTION BY THE CITRUS PSYLLA *TRIOZA ERYTREAE* (DEL GUERCIO) (HOMOPTERA: PSYLLIDAE)

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The psyllid, *Trioza erytreae*, lives on at least three indigenous host plants in Africa and has invaded citrus secondarily thus becoming economically important. Citrus is chosen as a host plant and as a site for oviposition in preference to the indigenous host plants. The sensory mechanisms mediating this choice were investigated. Colour cues are important in host plant location with olfactory and gustatory cues operating at short range in host plant selection. In this respect, the essential oils of the indigenous host plants of citrus psylla have been compared qualitatively and quantitatively with those of citrus employing gas chromatographic techniques. Laboratory studies are discussed in relation to field observations and host plant location and preferences by *T. erytreae* are compared with those in aphids in which the mechanisms involved are well documented.

SOME ASPECTS OF CERCAL SENSORY INPUT TO GIANT AXONS IN COCKROACHES

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The complexity of the dendritic fields of individual ventral giant axons in the cockroach suggests that these second-order sensory fibers perform an integrative function. Evidence from the recent electrophysiological studies of other laboratories support this. Cercal sensory hairs provide both phasic and tonic inputs to these giant fibers. Many of the short bristle hairs seem tuned to rather narrow bands of low frequency vibration. Sense cells associated with these hairs respond to short pulses of low frequency vibration with bursts of impulses which continue briefly following cessation of stimulation. Responses of these cells to bending of the hairs indicate some directional sensitivity in the sensilla. Studies of the fine structure of the sensilla indicate a symetric placement of the dendrites in the hair sockets, but an assymetry in socket structure which may account for this response directionality. Developmental characteristics of the cercal sensory fibers and giant fiber dendritic fields will be discussed. It is suggested that some giant fibers may function to integrate information from vibration receptors in the cercal sensory field to determine the behavioral response of the cockroach.

INTEGRATION BY IDENTIFIED NEURONS INVOLVED IN LOCUST BEHAVIOR

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A preparation has been developed which permits long-term intracellular recording from motor neurons and interneurons of locust ganglia. The penetrations are made from either the ventral or the dorsal surface of the nearly intact insect, permitting considerable freedom of movement. By utilizing two electrodes at a time in different neurons the input to synergists, antagonists, and sequentially related motorneurons could be examined. When one was placed in an interneuron and the other in a motorneuron, integrative functions were studied. After physiological study each identified neuron was filled with a dye, serially sectioned and reconstructed. In this way it has been found that insect neurons are anatomically as well as functionally prescribed. We have prepared a map showing the locations of most of the motorneurons and a few of the pre-motor interneurons of the metathoracic ganglion. Some information was obtained regarding integration in association with jumping, walking and flight.

THE ANTENNAE OF INSECTS AS AIR CURRENT SENSE ORGANS AND THEIR SIGNIFICANCE FOR FLIGHT CONTROL

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Behavioural investigations on insects of different orders show that their antennae function as sensors of air currents. The antennae of Orthoptera, Hymenoptera and Diptera, although different in structure, have similar functions in flight control. Flying insects hold their antennae stretched forward in flight position. The flagellae, being the structures which receive that stimulus, are pushed backward by pressure from frontal air currents. These passive movements are perceived by the mechanoreceptors of the pedicellus which are involved in the control of active antennal movements. The movements are described as antennal positioning reaction. Moreover they control wing stroke angles, wing stroke frequency, flight direction, and flying speed. Blowflies have two separate neuronal systems in the antenna. One is sensitive to steady deviations and controls the positioning reaction of the antenna, the other one is sensitive to vibrations and controls flight movements. In locusts hairs on the frons and vertex stimulate flight, whereas antennae inhibit it. They function as the sensory units of a negative feedback mechanism reducing flying speed and consumption of fuel.

THE NEURONAL BASIS OF SOUND PRODUCTION IN GRASSHOPPERS (ORTHOPTERA: ACRIDIDAE)

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The males of many grasshoppers perform courtship songs which are especially suitable for physiological studies because they are stereotyped and are easily elicited. One means of getting an insight into the neuronal organization of such behaviour is by analysis of the motor output. Muscle potentials were recorded with 30 µm steel wire electrodes. Apart from the constraints imposed by these thin and flexible leads the grasshopper is free to move. Up to 30 electrodes can be implanted simultaneously into the different thoracic muscles without noticeably influencing behaviour. Song is recorded simultaneously with the muscle activity. Since the muscle recordings are fairly selective, sound production can be analyzed in terms of the activity of a known group of motor units. As there is a fixed relationship between the action potentials of motoneurons and muscle units, the nervous activity can be deduced from the muscle recordings. The motor pattern underlying sound production is predominantly programmed by the central nervous system. Experiments suggest that sound production and courtship behaviour is controlled by interneurons (command fibers) distributed over greater areas within the CNS.

RELATIONSHIP BETWEEN BLOOD ION CONCENTRATION AND NERVOUS ACTIVITY IN THE COCKROACH

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It has been observed repeatedly that in insects like the locust or the cockroach, there was a correlation between the ionic content of the blood and the locomotor activity of the animal. The purpose of our experiments during the last decade has been to analyse the relationship between nerve activity and the blood ionic concentration. We have successively shown (1) that excitation processes in the giant axons of this insect are similar to those in the squid, (2) that the ionic composition of the extraaxonal fluid is certainly different from that of the haemolymph, and (3) that the nerve sheath which surrounds the nervous system is very effective in protecting the extracellular environment from changes in the blood ionic concentration. One can deduce from these results that the nerve function, even though conventional, is not or little affected by short term changes in the external ionic environment.

THE ROLE OF HORMONES IN THE REPRODUCTIVE BEHAVIOR OF WILD SILKMOTHS

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The saturniid moths do not feed; therefore, the females must mate and lay their eggs within a week. Both *Antheraea polyphemus* and *Hyalophora cecropia* virgin females release their sex pheromones ("call") in response to environmental signals - oak leaves and photoperiod respectively. In both cases this signal is relayed by the brain to the intrinsic neurosecretory cells of the corpora cardiaca which then release a "calling hormone" into the blood. After mating the presence of sperm in the bursa copulatrix causes the release of a factor from the bursa. This blood-borne factor acts on the brain to trigger the release of a second hormone from the intrinsic neurosecretory cells of the corpora cardiaca. The "oviposition hormone" is found in the blood of mated females and causes a fourfold increase in oviposition rate. Thus, in wild silkmoths the corpora cardiaca act as a switch to control reproductive behavior of both virgin and mated females.

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THE ECLOSION HORMONE: ITS DUAL ROLE AS A RELEASER AND AS A PRIMER OF INSECT BEHAVIOR

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The emergence of the adult moth is triggered by a neuro-hormone (the eclosion hormone) and involves a sequence of behavioral steps which begin with the pre-eclosion behavior and end with the spreading of the wings. The action of the eclosion hormone will be considered primarily in relation to these two pieces of behavior. Experiments with isolated abdomens and electrophysiological recordings from the deafferented abdominal nerve cord show that the pre-eclosion behavior is prepatterned into the abdominal ganglia. The hormone serves to release the entire 1¼ hour long behavior even in the absence of all sensory input. In the second piece of behavior, wing spreading, the eclosion hormone does not directly release the behavior, but it serves a primer function. Wing spreading requires a prior exposure to the hormone but the behavior is released by a suitable environmental stimulus. Once started this behavior then proceeds to completion irrespective of subsequent sensory input.

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REGULATION DES COMPORTEMENTS REPRODUCTEURS DES FEMELLES D'INSECTES - CAS PARTICULIERS DE *BLABERA CRANIIFER* ET *LABIDURA RIPARIA*

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L'analyse de la régulation des comportements reproducteurs des femelles d'Insectes est effectuée d'un point de vue éthologique et d'un point de vue physiologique. Nous montrons comment chez *Labidura riparia*, s'articulent les séquences de comportement alimentaire et de comportement reproducteur, comment dans celui-ci s'organise la série : creusement du terrier, ponte, soins aux oeufs, soins aux larves, dispersion de la famille. On analyse les rôles des comportements d'accouplement et des produits de l'accouplement (spermatozoides et produits des glandes annexes). En parallèle ces mêmes rôles de l'accouplement et de ses produits, sont analysés chez une Blatte ovovivipare en tant que responsables de la gestation et des variations de la réceptivité sexuelle.

NEUROSECRETORY AND CORPUS ALLATUM MEDIATED EFFECTS ON MALE SEXUAL BEHAVIOUR IN ACRIDIDS

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The corpora allata (CA) completely control male sexual behaviour in the desert and red locusts and almost completely in the grasshopper, *Oedipoda miniata*. Allatectomized males of the African migratory locust, however, exhibit distinct though subnormal mating behaviour, which is considerably influenced by the kind of locusts which are nearby (fellow allatectomized males, females, control males). In this species the CA differentially affect sexual behaviour in different phases; the effect is marked in crowded males, but slight in isolated ones.

Selective electrocoagulation of either the C-, or the A + B median neurosecretory cells demonstrated in the male African migratory locust, that: (1) The C-cells completely control mating behaviour by a primary effect which is not mediated through the CA; (2) By activating the CA the C-cells also exert a secondary effect on sexual behaviour; and (3) The A+B-cells have no effect on mating behaviour.

With regard to male sexual behaviour, the nervous system probably constitutes the eventual target organ of these endocrines, but their mode of action (direct - indirect; specific - general) on this target organ remains to be investigated.

THE DEVELOPMENT OF THE FLIGHT PATTERN IN LOCUSTS

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The responses of locusts to air currents and light flashes were observed throughout the animals' development. During exposure to such stimuli even locust larvae assume a position that resembles the flight position of the adults. Older larvae remain in this "flight" position longer than do younger ones. Electrical recordings of the activity of the thick thoracic muscles reveal a tonic activity in the "flying" larvae. However, the unequivocal, typical flight pattern is first seen on the day of imaginal ecdysis. Within the next few weeks following the last ecdysis the wing-beat frequency increases. A learning process is unlikely to be involved in flight pattern formation.

DEVELOPMENT OF FUNCTIONAL CONNECTIONS IN THE NEURONES CONTROLLING FLIGHT IN LOCUSTS

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To investigate the specificity of contacts between nerve cells the normal sequence of events during the establishment of synaptic connections must be understood. Behaviour which appears late in the life cycle of an insect provides promising material for a developmental study as changes are restricted to a few neurones. Flight is a suitable example.

In the locust *Chortoicetes terminifera* flight developes in three phases: (1) synchronous firing in all flight muscles in juveniles; (2) establishment of the characteristic adult pattern of alternate firing in antagonistic muscles at about the time of the last moult; and (3) gradual increase in wing beat frequency in the first days of adult life. The critical period when new connections become functional is therefore at the beginning of the adult instar when the typical flight pattern is established.

Changes in the activity of some of the flight motor neurones have been investigated over this critical period by intracellular recording. The morphology of the motor neurones has been studied by injecting dyes into the cells during the same period.

SPECIFICITY AND REGENERATION IN COCKROACH MOTORNEURONS

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The connexions of single identified motorneurons have been studied in the thorax ganglia of the cockroach, *Periplaneta americana*. Selected cell bodies have been identified on purely morphological criteria from one animal to another. Similarly, serially homologous cell bodies have been identified from one segmental ganglion to another. Their connexions to particular limb muscles have been demonstrated by intracellular stimulation through the cell body and subsequent marking with procian yellow dye. These connexions have then been studied under various experimental conditions, especially following nerve transection and limb transplantation.

SPECIFICITY IN THE REGENERATING CERCAL NERVES OF THE HOUSE CRICKET, *ACHETA DOMESTICUS*

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The abdominal cerci of *Acheta domesticus* are sensory structures whose sensory nerves project to the giant interneurones of the abdominal nerve cord. The cerci regenerate vigorously and functional contact is reorganised with the giant interneurones, with a high degree of accuracy as estimated in records of responses elicited in response to stimulation of the cerci. The only category of abnormal connection so far recognised arises during asymmetric development of regeneration of cerci, when contralateral connections have been detected anatomically and physiologically. Dendrites of interneurones left vacant by the absence of their normal input may be invaded by non-cercal input that is not detected in the normal animal.

A THEORY OF INSECT BRAIN FUNCTION

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Profound differences in brain structure are found between social Hymenoptera, termites, and non-social insects. All social insects have well-developed corpora pedunculata. In termites, the stalk and lobe system is particularly well-developed; in social Hymenoptera the calyces are also very highly developed. By comparing the calyx structure of ants, bees and termites, it is possible to identify, provisionally, regions concerned with visual memory, olfaction, and tactile senses. A model for the action of the mushroom bodies is proposed, based upon neuroanatomical evidence.

The effect of brain lesions on the orientation of honeybees, termites and locusts to olfactory attractants and repellents will be described. Stereotyped olfactory and other responses occur in insects with calyces removed, but mechanisms of transition between behaviour patterns are disrupted. Experiments on foraging and conditioned honeybees have been made to identify the neurones involved in protein synthesis during learning and to determine the importance of the calyces in learning.

THE RESPONSE OF THE WOODWASP, *SIREX NOCTILIO* F. TO HOST TREE VOLATILES

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The major host tree of *Sirex noctilio* in Australia and New Zealand is *Pinus radiata* D. Don. Female wasps have been attracted in the field to trees baited with extracts of fresh phloem and also dilute solutions of the pinenes (α- and β-) in acetone and hexane.

The insect's response to these and other host tree materials was investigated in the laboratory utilizing (i) the whole insect in a flight mill olfactometer, and (ii) the antennae in EAG studies.

Characteristic responses to test materials have been detected in both bioassay methods employed and changes in the thresholds of response with age of insect have been observed.

These results, and those obtained from tree physiology studies, have permitted a satisfactory interpretation of the factors involved in the host tree location and oviposition behaviour of *S. noctilio*.

SOUND PRODUCTION IN SOME EUROPEAN PLANTHOPPERS (*EUSCELIS* SPP.)

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The paper describes the acoustical signals in some European planthoppers of the genus *Euscelis*. The sounds of males are answered by females and both sexes communicate intraspecifically by species-specific sound patterns. Species which are sympatric have rather different acoustical signals, allopatric species on the other hand may show very similar sounds, but one exception to this principle will be demonstrated and discussed. The question of whether these two related forms are distinct species or only two races of the same species will be discussed.

MECHANISM OF SOUND PRODUCTION IN AUSTRALIAN CICADAS

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The physiological mechanism by which the natural song is produced has been studied in detail in four species of Australian cicadas (Cicadidae: Homoptera). The basic apparatus is the same as for other cicadas, consisting of tymbal, tymbal muscle, tensor muscle and expanded tracheal air chamber. In three of the species studied the tymbal muscles are neurogenic and contract simultaneously, a mechanism which has not been described before. In the fourth species, the mechanism appears similar to that described recently for the American periodical cicada. The function of the tracheal air sacs and the tymbal covers in certain species is also described.

THE MALE CALLING SONG OF THE BIG BROWN CRICKET (*BRACHYTRYPES PORTENTOSUS* LICHT., GRYLLIDAE: ORTHOPTERA) AND THE STRUCTURE OF ITS STRIDULATORY APPARATUS

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In loudness, shrillness and intensity of song, the male of the big brown cricket excels all other insects. It is a long continued, high-pitched and uniform "krirn - rn - rn - rn -..." of which the "r" is more distinct than the "n". Analysis of the song using the oscillograph has given details of its physical qualities.

The pars stridens on the ventral surface of each tegmen is provided with 49 teeth on a vein length of 3.9 mm. Inner to the plectrum on the antero-internal edges both dorsally and ventrally are areas provided with long setae. A large drum is also present on each tegmen. It would appear that the capacity to make the continuous calling song (often lasting over 15 minutes) in this cricket may be due to the ability of all parts of the stridulatory apparatus, viz., the plectrum, the pars stridens, the setae on the dorsal and ventral sides of the tegmina near the plectrum, to contribute to its production.

THE ATTRACTION OF FRUIT FLIES (DIPTERA: TEPHRITIDAE) TO CHEMICAL LURES

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In a recent study of the taxonomy and zoogeography of Dacini from the South Pacific area, specimens were collected in Steiner male lure traps. The traps were positioned on 26 islands and north-east Australia, and by this method, 79 species were collected.

The lures were found to be of two types on the basis of their attractiveness to species: (a) cue lure group, comprising cue lure, 1-(p-hydroxyphenyl)-butan-3-one and 1-(p-acetoxyphenyl)-butan-3-one; (b) methyl eugenol. No species was attracted to both the cue lure group and methyl eugenol. Most species within the groups of morphologically similar species were attracted to only one type of lure.

RESULTS OF AN INTERDISCIPLINARY STUDY ON HOST DISCRIMINATION IN *PSEUDEUCOILA BOCHEI* WELD (HYM: CYNIPIDAE); BEHAVIOURAL, MORPHOLOGICAL AND ECOLOGICAL ASPECTS

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The female of *Pseudeucoila bochei* lays her eggs in larvae of *Drosophila* species. When a female has found the host medium, she walks over the surface pricking her ovipositor into the substratum. Exact localization of a host takes place by means of the ovipositor. When the ovipositor hits a host it may pierce the host's skin and stay in this position for a few seconds. This may lead to egglaying in which case the wasp extends her ovipositor further, or to rejection. Rejection of a host is observec only after the ovipositor has been inserted in the host.

The distribution of parasite eggs over the hosts is much more regular than a Poisson distribution. There exists a strong discrimination between uparasitized and parasitized hosts. Discrimination in *Pseudeucoila* seems to be accomplished by chemoreceptors at the ovipositor. The parasite appears to distinguish hosts with different numbers of eggs and prefers hosts with the lowest numbers. Mathematical models were worked out to describe the distributions found.

ON THE FEEDING AND LOCOMOTORY ACTIVITIES OF *ZONOCERUS VARIEGATUS* (L.) (ORTHOPTERA: ACRIDOIDEA)

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Field observations have shown that the *first, second,* and *third* instar larvae of *Zonocerus variegatus* feed almost exclusively on weeds, notably *Eupatorium odoratum* and *Aspilia latifolia.* The recent widespread occurrence of *Eupatorium* in many parts of the western state of Nigeria probably accounts for the increasing abundance of *Zonocerus.* The *fourth, fifth* and *sixth* instars and the adults cause considerable damage to crops such as cassava, citrus, banana/plantain.

Spontaneous flight was very rare in the field, but about 40-50% of mature adults flew over short distances when disturbed, especially during bright sunshine. Aktograph experiments show that the patterns of locomotory activity of the sixth instar larvae and the adults were similar. Activity occurred only during 0700-1800 hours with a peak at 1400-1600 hours. Constant illumination (approximately 630 lux) and temperature (30°C) destroyed the normal rhythm of activity of the adults.

A RE-EVALUATION OF THE 'STYROPOR METHOD' FOR ASSESSING PHAGOSTIMULATION IN THE LARVAE OF SOME PHYTOPHAGOUS INSECTS

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The so-called 'styropor method', in which lamellae of foamed polystyrene treated with phagostimulatory substances are fed upon by larvae of phytophagous insects (e.g. *Spodoptera littoralis, Cydia pomonella, Ectomyelois ceratoniae, Gnorimoschema operculella,* etc.) was developed by Meisner and Ascher and has been employed in several studies. The following factors pertaining to the method were now investigated with larvae of *S. littoralis,* feeding on lamellae treated with a 5% sucrose solution as model phagostimulant:

1. The type of foamed polystyrene
2. Thickness of the lamellae
3. Offering or not offering water
4. The size of the larvae
5. The effect of prestarvation
6. Conducting the experiments in light or darkness

The most advantageous conditions for conducting phagostimulatory assays with the 'styropor method' with *S. littoralis* could thus be determined.

A further interesting use of the method in bark beetle research is demonstrated.

AN EXPERIMENTAL ANALYSIS OF THE INFLUENCE OF PHOTOPERIOD AND TEMPERATURE ON THE OVIPOSITION BEHAVIOUR OF *CHORTOICETES TERMINIFERA* WALK.

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Photoperiod and temperature exert an important influence on the egg-pod morphology of *Chortoicetes terminifera.* Insects subjected to long-day conditions, or to an increase in photoperiod during development tend to lay straight pods. Under short-day conditions, or where photoperiod decreases during development, egg-pods are generally short, curved and/or laid obliquely. High temperatures, or an increment in temperature during development are associated with the production of long pods, whilst low temperatures, or a reduction in rearing temperature tend to favour the deposition of short pods. These findings are consistent with field observations. Their significance in relation to the development and survival of eggs during different seasons is examined and shown to be ecologically sound.

SECTION NO. 5

BIOCHEMISTRY

CONVENOR: D. GILMOUR

GENERATION OF FLIGHT MOTOR ACTIVITY

G. Hoyle

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Since D.M. Wildon's analyses of the flight motor pattern in locusts an intensive search has been made for the underlying removal mechanisms generally believed to be a form of intrinsic oscillator. The motor neurons of the mesothoracic ganglion were mapped using Procian dye injection and direct stimulation by David Bentley, but a specific search for the oscillator made by C.H. Page at Stanford failed to reveal any signs of it. In the metathoracic ganglion Malcolm Burrows and G. Hoyle located two flight motor neurons which were recorded from intracellulary during flight rhythms. In each, a depolarization plateau appears after air-puff stimulation, leading into large (over 20mV peak to peak) smooth membrane potential oscillations at characteristic flight frequency. Single spikes, doublets, and triplets are generated in each neuron by the rising phase of the wave, the number being determined by the rate of the rise, as well as the amplitude, of the wave. These correlate exactly with spikes in the basalar and subalar dorsoventral flight muscles.

NEURONAL CIRCUITS IN THE FLIGHT SYSTEM OF THE LOCUST

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Stable intracellular recordings from the somata of flight motorneurons during flight of the locust *Chortoicetes* have revealed certain central neuronal circuits. The motorneurons supplying the metathoracic tergosternal muscles on either side of the body receive major synaptic inputs in common. A spike in either neuron activates a reverberatory circuit which feeds back excitatory synaptic input to that neuron with a delay equal to the flight period. The spike also activates other circuits which feed excitation onto the contralateral neuron with the same delay. Under suitable conditions the two neurons will oscillate. Other motorneurons are linked by circuits with delays appropriate to the phase in which they fire in flight. Dye injection has revealed the dendritic topography of these motorneurons.

ELECTRICAL ACTIVITY IN ASYNCHRONOUS MUSCLES AND FLIGHT CONTROL

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Changes in the patterns of electrical and mechanical activity in the asynchronous flight muscles of honeybees were compared with changes in flight behavior. Large increases in the speed of bees flying on a turnabout were induced by moving a patterned corridor about the moving bee. Increases in the dorsoventral muscle's action potential frequency were positively correlated to increases in flight speed and changes in wingbeat frequency were negatively correlated to speed changes, however, changes in the dorsolongitudinal muscle's potential frequency were not significantly related to changes in flight rate. The observed changes in action potential and wingbeat frequencies were subjected to a multiple regression analysis and the maneuvers predicted by the resulting equation correspond well to the actual changes in flight speed. The results suggest that the dorsoventral muscles are the most important muscles for the generation of thrust, therefore thrust is generated primarily in the upstroke of the wingcycle.

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THE UTILIZATION OF CARBOHYDRATES BY INSECTS DURING FLIGHT

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In the development of flight, insects show a remarkable parallel evolutión of structure as well as biochemical mechanisms of energy production. The unusually high energy requirements of insects for flight is related not only to their ability to fly at incredibly high rates but also for unusually long periods of time. Thus wing rates in the Diptera may reach 10,000 beats per minute, while the honey bee uses 2,500 calories per gram of muscle per hour over long periods of sustained flight in the field. Morphological adaptations include the development of indirect flight muscle and the presence of giant sarcosomes. Work by Gilmour, Sacktor, Chefurka, Slater and others has produced a picture of aerobic and anaerobic metabolism of carbohydrates not dissimilar to that found in bacteria as well as in vertebrate liver and muscle. Special biochemical adaptations are the preponderance of α-glycerophosphate dehydrogenase and the presence of the circulating, non-reducing disaccharide trehalose. From research on the housefly, carried on for well over a decade by Rockstein and co-workers, emerges a remarkable pattern of biochemical changes related to the aging of flight ability, which suggests the important role of such enzyme systems as α-glycerophosphate dehydrogenase, Mg-activated ATPase, arginine phosphokinase, as well as the distribution of thiamine, trehalose, and arginine, in the maturation as well as the onset of failure of flight ability. In prospect, the highly consistent generation-after-generation reproducibility of such data suggests the primary role of a genetic programme as the basis for the senescence of this particular motor function and, therefore, the exploration of the level in the molecular genetic nexus at which such control may lie.

SOME ASPECTS OF THE STRUCTURE OF FIBRILLAR FLIGHT MUSCLES

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The fibrillar flight muscles are distinguished from non-fibrillar muscles by the following features:

1. the circular myofibrils made up of a precise lattice of thick and thin filaments,
2. the lack of a distinct I-band,
3. the closely packed, large mitochondria,
4. the paucity of sarcoplasmic reticulum.

Some other details of their structure are still a matter for dispute.

Auber and Couteaux in describing the Z-line of *Calliphora* noticed that small areas of amorphous material can be seen in the spaces in the lattice which further from the Z-line would be occupied by the thick filaments. They wondered if this material might in some way connect the thick filaments to the Z-line. This observation was siezed upon by physiologists who were seeking a structure which could be responsible for the peculiar elastic properties of fibrillar flight muscle. No evidence was found for such material in *Lethocerus* muscle. Other structural evidence for connexions between the thick filaments and the Z-line has been put forward, but it will be shown that this evidence is fallacious.

A characteristic of fibrillar flight muscle, which has received little attention, is the precise regularity of the filament lattice, compared to that in other types of striated muscle. This regularity is responsible for the moiré patterns seen in longitudinal sections of myofibrils. The significance of this characteristic is not known.

Lastly, some aspects of the changes which occur during ageing in fibrillar muscle will be discussed.

IS THERE CROSS-BRIDGE SYNCHRONY IN OSCILLATING INSECT FLIGHT MUSCLE?

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Two major obstacles prevent the direct observation of the motion of the myosin cross-bridges in striated muscle fibres. The first is that the mechanical cycling of the cross-bridges is fast (*c.* 100 Hz), too fast to be measured with the time resolution of the presently-available X-ray diffraction machines. The second problem is that the cross-bridges may not be synchronous in their action, even under optimal conditions. The first of these problems has now been overcome by the development of a technique in which the polarization of tryptophan fluorescence (P_1) can be measured with a time resolution of 2 msec. and which appears to report on the orientation of the myosin (specifically the S1 subfragment) cross-bridge. This technique which was initially developed using glycerinated rabbit psoas myofibres, has now been used on single glycerinated insect (*Lethocerus maximus*) dorsal longitudinal flight muscle fibres. The order of the P_1 values follows that determined from psoas myofibres, viz. Relaxation (pCa=8) > Contraction (pCa=6) > Rigor. While P_1 appears to reflect cross-bridge orientation, the results do not necessarily imply that their movement is synchronous.

ENDOCRINE REGULATION OF SPECIFIC PROTEIN SYNTHESIS

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Immunologically identifiable female-specific proteins are essential for egg maturation in several species of insects. With the exception of the saturniid moths, the synthesis of these proteins is under the control of the corpus allatum hormone (JH). Both isolated, naturally occurring JHs and the lower homologue epoxyfarnesenic acid caused the synthesis of the female-specific protein in *Leucophaea maderae*. Actinomycin D completely blocked the synthesis of the specific protein. JH also increased the synthesis of total sodium dodecylsulfate-phenol extractable RNA. In a complete cell-free system, RNA extracted from egg-maturing females stimulated female-specific protein synthesis. RNA from males or allatectomized females did not stimulate this specific protein synthesis. The sum of the data appears to support Karlson's hypothesis on hormonal control of transcription of specific messenger.

ACTION OF JUVENILE HORMONE IN A HEMIMETABOLOUS INSECT

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Nymphs of the large milkweed bug were injected with juvenile hormone at 4 hours after ecdysis into the fifth instar. Controls were injected with acetone. One µl of ^{3}H-leucine was injected into different groups of these bugs at selected intervals throughout the fifth stadium. One hour after the ^{3}H-leucine injection, hemolymph was taken and it was subjected to disc gel electrophoresis. Some of the gels were stained for protein and some were prepared for liquid scintillation counting. Juvenile hormone caused band 8 to decrease in concentration but to increase in synthetic rate. A series of histochemical stains were performed on the gels and band 8 was found to contain acid phosphatase. Experiments with puromycin and Actinomycin D indicated that the control by juvenile hormone of the synthesis of the protein in band 8 was at the transcriptional level.

DEVELOPMENT OF THE FOLLICULAR CELLS AND CHORION PROTEIN SYNTHESIS IN SATURNIID MOTHS

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The follicular epithelium of silkmoths is particularly favourable for studies of differentiation-specific protein synthesis. Each follicle consists of a single layer of polyploid epithelial cells, enveloping the oocyte and the nurse cells. The ovariole consists of a sequence of progressively more mature follicles, so that analysis of sequentially dissected follicles is tantamount to a study of the developing follicle over time. Differentiation of the follicular cells involves the sequential elaboration of at least three classes of proteins. The first is a glycoprotein produced during vitellogenesis and apparently involved in yolk binding and uptake by the oocyte. The second is the proteins of the vitelline membrane. Finally, the third is the proteins of the eggshell (chorion). Chorion consists of more than a dozen proteins, unusually small in size (7,000-18,000 MW) and peculiar in amino acid composition. Species differences in these proteins exist, but the proteins of sphingids, saturniids and *Bombyx mori* also show considerable similarity. Each chorion protein is apparently synthesized as a distinct component; there is no inter-conversion of proteins, either within the cytoplasm or in the extracellular chorion. During development, the follicular cells undergo sequential, rapid and highly repeatable transitions in protein biosynthesis. Synthesis of non-secretory proteins is markedly depressed as the follicular cells embark on chorion production. Moreover, the developmental kinetics of synthesis vary for different chorion proteins, so that at each point in time the follicular cells show a distinctive profile of protein biosynthesis. We will report work on the mechanisms controlling changing rates of specific protein biosynthesis in this tissue.

A NEW PROTEIN-DEPENDENT NEUROSECRETORY PRODUCT INVOLVED IN OOGENESIS IN *LUCILIA CUPRINA* (WIED.) (DIPTERA: CALLIPHORIDAE)

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Female *Lucilia cuprina* fed amounts of protein inadequate for complete egg development develop their eggs to a stage similar to that of allatectomised females. If such underfed females are allatectomised, then 80% mature their eggs after a protein meal, indicating that the corpus allatum is not involved. A critical period for production of a neurosecretory product was demonstrated by decapitating females up to 15 hours before 50% of the females would be expected to have had ovaries at the relevant stage of development.

Histological investigations, using the light and electron microscopes, have shown that a marked change in the method and rate of yolk formation take place at the stage of ovarian development affected. This suggests that the neurosecretory product involved plays a direct gonadotrophic role. This conclusion is consistent with results obtained by other researchers on *Aedes aegypti* and *Sarcophaga bullata*.

JUVENILE HORMONE AND INSECT EMBRYONIC DEVELOPMENT

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Cecropia juvenile hormone (JH) or its analogues applied to either adult female insects or to freshly oviposited eggs prevents hatching of the eggs. Application of either Cecropia JH or its analogues to *Pyrrhocoris apterus* or to *Hyalophora cecropia* during the terminal phases of oogenesis blocks subsequent embryonic development at the blastoderm stage. Smaller doses at this time or the same dose during vitellogenesis interfere later with blastokinesis. Eggs treated with JH or its analogues after germ band formation hatch but delayed morphogenetic effects are seen in larval life or at metamorphosis, so that reproductive maturity is not attained. In *Pyrrhocoris* we have shown that the prevention of metamorphosis is due to a failure of the shutting-off of the corpus allatum of fifth instar larvae treated with JH as late embryos. The mode of action of JH in embryogenesis and its potential application as an ovicide in insect control will be discussed.

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THE INFLUENCE OF EXTERNALLY APPLIED JUVENILE HORMONE ANALOGS ON INSECT DEVELOPMENT

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New JH analogs, more potent and more stable than natural JH, do not seem to differ significantly in their effects on the insect beyond the quantitative aspects. Application techniques like substrate treatment, food admixture, vapor treatment etc. can increase the effect on metamorphosis compared with the effect of topical application. These treatments have also produced a rich variety of different pigmentation effects in larvae. These effects do appear in larvae of all stages and are usually reversed in subsequent instars when the exposure is terminated.

Examples are the green (Solitary phase) coloration in various Acrididae, a deep red pigmentation in larvae of *Heliothis* (Noctuidae), disappearance of the green color in larvae of *Manduca* (Sphingidae), and the onset of a deep black melanization in nymphs and adults of the leafhopper *Dalbulus* (Homoptera).

Under continuous exposure these pigmentation effects appear to be strongly correlated with the dose and the final effect on metamorphosis.

The most effective route of entry is difficult to establish, it may be repeated contact, ingestion or vapor.

JUVENOIDS, THEIR WAY OF ACTION AND THEIR THEORETICAL AND PRACTICAL IMPORTANCE

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Entocanes, a new type of means in insect pest control - Juvenoids or juvenile hormone analogues and their promise - History of their discovery - Relation to the juvenile hormone - Chemistry - Effect on growth - Effect on morphogenesis - Effect on reproduction - Common basis of their effects - Action in embryogenesis - Action in postembryonic development - Action in adults: ovarian follicle cells, accessory glands, wing muscles ripening and degeneration - The principle of action: conversion of the gradient growth into a proportionate one - Theoretical meaning: a possibility of the most physiological experimental interference with the principle of morphogenesis - Present conclusions - Preferences for insect control - Activity - Specificity of action - Harmlessness to other animals - Effect on entomophagous insects - Field experience - Questions of application - Perspectives.

THE INFLUENCE OF JUVENILE HORMONE ON THE POST-EMBRYONIC DEVELOPMENT OF *DROSOPHILA MELANOGASTER*

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The influence of a synthetic racemic mixture of Cecropia C_{18} juvenile hormone (JH) on the metamorphosis of *Drosophila melanogaster* was studied by topical application to different stages of larval, pharate pupal and pharate adult development. Supernumerary larval molt was not observed when JH was applied to different larval instars. JH, when applied to second and early third instar larvae of various non-tumor strains, induced pseudotumor formation phenocopying the *tu* gene. Late third instar larvae and pharate pupae responded to JH by producing 'adults' with reduced brown pigmentation of the eyes, and pigmentation of general body surface, defective cuticle and chetae and partially differentiated internal organs. These adults also failed to emerge. By comparing the effects of JH with those of Minute loci on adult development of *Drosophila*, it is suggested that JH probably influences the production of soluble or transfer RNA to bring about lethal derangements of metamorphosis.

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HORMONAL HETEROPHYLLY

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Continued study of invertebrate hormones has revealed implications not only in relation to invertebrates themselves but also for mammals in general and the biosphere important to man as well. In early work, crude extracts of *Bombyx* showed increased RNA and DNA synthesis in mammalian cells after exposure to ecdysones, although no trace of these hormones was found when human tissues were extracted. Wound healing was not affected, but QO_2 was enhanced by this hormone when exogenous substrate was added. Fine structure of hepatic tissue perfused with ecdysone showed alignment and prominence of rough endoplasmic reticulum, vacuoles, and possible alterations in membranes. Subsequent work with crystalline ecdysterone confirms that the rate of protein and RNA synthesis in mammals is increased by the hormone, the level of blood glucose is lowered in diabetic animals, and cholesterol levels are also affected. Inhibition of mammalian neoplastic growth by crude extracts has not been confirmed with crystalline ecdysterone in all experiments, but results are equivocal in others. Whether these effects are specific and whether transphylar target mechanisms exist in tissues removed by evolutionary epochs remain to be determined. Evidence will be presented to support the actions of hormones in mammals and to justify extension of this direction of inquiry.

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ECDYSONE-BINDING PROTEINS IN NUCLEI AND CHROMATIN FROM *DROSOPHILA* SALIVARY GLANDS

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Complexes of radioactive hormone and protein(s) can be isolated from the salivary glands of *Drosophila hydei* after treatment with tritium labelled ecdysone. Fractions containing these complexes have been obtained from cytoplasmic and nuclear extracts by means of gel-filtration, density gradient centrifugation and agar electrophoresis.

A 8S hormoneacceptor, derived from the cytoplasm, is obtained by extractions at low ionic strength. Following extraction with 0.4 M KCl, a complex sedimenting at approximately 4S is demonstrable.

Small amounts of radioactive ecdysone are associated with chromatin prepared from glands which were incubated with the hormone. The major portion of chromatin-bound hormone is found in the non-histone protein fraction. Purified chromatin from untreated glands binds ecdysone upon *in vitro* incubation, but to a lesser extent than *in vivo* conditions.

THE CHEMISTRY AND BIOSYNTHESIS OF INSECT MOULTING HORMONES

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A variety of labelled sterol derivatives which are possible moulting hormone precursors and a number of labelled ecdysone analogues have been synthesised and their metabolism studied *in vivo* in the blowfly *Calliphora stygia*. The conclusions that can be drawn from these studies about the biosynthesis of the moulting hormone crustecdysone in *Calliphora stygia* will be discussed.

BEHAVIOURAL CONTROL OF ECDYSONE RELEASE DURING PUPATION OF THE COLORADO POTATO BEETLE

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Mature larvae of the Colorado potato beetle, prior to pupation, perform positive geotatic behavior which is influenced by moisture and light. A sufficient period of time for the larvae to remain in the soil is essential for pupation. Pupation can be prevented experimentally by suspending the larva from a thread. Under this non-confined condition, normal pupation can be induced by the injection of α-ecdysone. Behavioral evidence indicates that the release of ecdysone is mediated through thigmotactic responses, since mature larvae which are not allowed to dig into soil can pupate normally under close confinement. Experiments with mature larvae decapitated either prior to or at the time of cessation of feeding resulted in headless pupae regardless whether or not confinement was enforced. The available evidence indicates that the secretion of ecdysone by the prothoracic glands is under the inhibition of the brain. Sensory input through body confinement causes the brain to abolish such inhibition and normal pupation can proceed.

ISOLATION AND PROPERTIES OF INSECT BRAIN HORMONE

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Extraction and purification of the prothoracico-tropic hormone has been done from the whole head of *Bombyx* instead of extraction from the brain only. After removal of cholesterol, lipids, nucleic acids, macromolecules and many other substances, peptides fraction showed a strong brain hormone activity. The head of an adult silkworm contains brain hormone of at least 50 *Samia* units. The brain hormone seems to be water-soluble, heat-stable and resistant to certain peptidases but appears to be dialyzable.

On the other hand, it was found that certain ions and amino acids caused brainless *Bombyx* pupae to emerge at an incredibly high rate. It, however, caused no or only minor effects on the brainless *Samia* pupae. Non-specific agents mimicking brain hormone also will be discussed.

NEW RESULTS ON THE MODE OF ACTION OF THE BRAIN NEUROHORMONE ON INSECT DEVELOPMENT

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The brain neurohormone (brain implants, brain homogenates, homogenates of the corpora cardiaca, the activation-factor of gel-filtrated brain-extracts) increases RNA-activity of the prothoracic glands, as demonstrated both by histochemical methods including cytophotometry and by the incorporation rate of H^3-uridine. The experiments were performed *in vivo* on *Periplaneta americana* and *in vitro* on *Mamestra brassicae* with identical results. A detailed analysis of the so induced RNA-pattern after separation with polyacrylamid electrophoresis is demonstrated and discussed.

The substances produced by activation of the prothoracic glands could be separated by thin-layer chromatography and demonstrated by ultra-violet spectroscopy. Mass spectrometry of these substances showed that they are an unseparated mixture of different fatty acids. The relationship of these fatty acids to the function hitherto accepted for the prothoracic gland is still unknown.

Measuring the membrane potentials of the cells of the prothoracic glands of *Galleria mellonella* revealed a significant increase stimulated by the brain-neurohormone. It may be concluded from these results, that the brain-neurohormone controls the activity of the prothoracic glands of *Galleria* as a blood-borne (hormonal) as well as a nerve-axon-carried (humoral) factor.

SCLEROTIZATION OF THE COCKROACH CUTICLE

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Cuticle sclerotization by the American cockroach involves the cross-linking of protein polymers by several diphenols. The major diphenol appears to be *N*-acetyldopamine but 3,4-dihydroxyphenylacetic acid, 3,4-dihydroxybenzoic acid and traces of a beta hydroxylated dihydroxy compounds may also play an important role. The synthesis of these diphenols, and their subsequent binding to haemolymph proteins have been investigated in regard to the moulting cycle.

The proteins involved have been assayed and their time of synthesis and incorporation into the cuticle have been followed. These data indicate that a number of haemolymph proteins can be synthesized by a variety of cell types and that various aggregations occur before and during cuticle deposition.

Further studies have shown that bursicon, the tanning hormone, mediates some of these processes and that the hormone may have a far broader mode of action than previously reported.

PHENOLOXIDASE SYSTEMS

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There are two kinds of phenoloxidase systems in insects: viz., a soluble *o*-diphenoloxidase (tyrosinase) in hemolymph and insoluble *p*-diphenoloxidase (laccase) in cuticles. Hemolymphal oxidase occurs as an inactive pre-enzyme, which can be activated by incubation with a cuticular activator of protein nature. The pre-enzyme and the activator have been purified in a homogeneous state from *Bombyx* silkworm. Several lines of evidence indicate that the activation involves partial proteolysis of the pre-enzyme. *p*-Diphenoloxidase has also been purified from pupal cuticles of the silkworm. The sharp rise of the oxidase activity at the time of cuticular pigmentation indicates the significance of *p*-diphenoloxidase in the darkening and hardening of the cuticles.

CONTRASTING PATTERNS OF GENE ACTIVITY IN INSECT DEVELOPMENT

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Cell differentiation during both larval and adult phases of development in holometabolous insects proceeds in many tissues by a series of discrete steps, each characterised by well defined sets of gene activities. Using the blowfly *Calliphora*, changes in the patterns of chromosome puffing and dispersion have been followed in relation to transcription and replication in the polytene chromosomes of larval fat body and salivary gland, and comparisons have been made with footpad and trichogen nuclei in the pharate adult.

Sequential changes in gene activity are particularly clearly seen in the larval fat body of *Calliphora*, where the major cell function switches abruptly during third instar from synthesis and secretion (0.4 µg protein/cell/day) to protein uptake and formation of storage granules. Intense transcriptive activity in this tissue involves dispersed segments of the genome intimately related in tissue-specific patterns to nucleolar ribonucleoprotein. Chromosome puffing is seen here as a more restricted phenomenon involving individual bands (or small clusters of bands) at later developmental stages.

SOME ASPECTS OF PROTEIN METABOLISM DURING METAMORPHOSIS OF THE FLY *PHORMIA REGINA* MEIG.

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As an experimental approach to the question of whether the same gene (or genes) codes for homologous proteins during the larval and adult stages of a holometabolic insect, we have examined two different fructose diphosphate aldolases (E.C. 4.1.2.13) from muscle and fat-body of larval and adult *Phormia regina*. The enzymes derived from these two tissues are different proteins which enzymatically bear much the same relationship to each other as do their vertebrate muscle and liver counterparts. The larval and adult insect muscle enzymes are virtually indistinguishable as judged by immunological, enzymatic and hydrodynamic criteria. Despite certain similarities, they are nevertheless clearly different from rabbit muscle aldolase. The two fat-body enzymes have proved extremely difficult to purify; based on impure preparations they appear to be similar in some respects yet different in others. The possible implications of these findings will be discussed.

HORMONAL CONTROL OF CHROMOSOME PUFFING

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To distinguish between "antagonistic" and "non-antagonistic" effects of hormones on chromosomal puffs, salivary glands were examined. Do ecdysone or juvenile hormone (JH) affect the same or different chromosomal loci in *Chironomus*, and what other developmental effects occur? The evidence suggests that JH and ecdysone affect different chromosomal puffs. For example, in *C. thummi* Balbiani ring b (BR-b) is enlarged by JH but is unresponsive to ecdysone. IIId-1, an ecdysone puff, according to Kroeger is unaffected by JH, while BR-c is unaffected by either. Molting is ecdysone dependent and is unaltered by exogenous JH. JH, administered at metamorphosis, induces puffing changes and developmental abnormalties.

These results are consistent with a non-antagonistic effect of JH and ecdysone in regulating gene activity. The hormones cause specific and separate changes in gene activity resulting in normal growth and metamorphosis.

HORMONAL CONTROL OF PROTEIN SYNTHESIS DURING INSECT DEVELOPMENT

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The patterns of individual proteins in different tissues undergo definite changes during pupal-adult transformation of the silkworm *Hyalophora cecropia*. The composition of blood is reflective of these changes. Application of juvenile hormone, ecdysone and mixture of these two hormones to the pupal stages induces a specific response in the synthesis of the blood proteins. The autoradiographs of acrylamide gel electrophoresis of isotopically labelled proteins are examined. The effects of hormones on the rate of synthesis is computed on the basis of densitometric quantification of isotope incorporation in specific proteins. The mode of action of insect hormones is discussed in the light of these observations.

CHARACTERISTICS OF PROTEINS AND NUCLEIC ACIDS DURING OOGENESIS AND EMBRYOGENESIS OF *MUSCA DOMESTICA* L.

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During each oviposition cycle there is a cyclic increase and decrease of total protein, RNA, and DNA in the ovaries - with protein and RNA at maxima at the time of oviposition but with DNA decreasing prior to oviposition. In fertile eggs held at 37°C there is an initial lag period of 1-2 hr in DNA synthesis, followed by a rapid many-fold increase. LDH synthesis parallels DNA synthesis and its isozymes increase from 2 to 5 during embryogenesis. RNA-DNA hybridization studies of the nucleic acids from fertile eggs at early and late stages of embryogenesis and from unfertilized eggs confirm the synthesis of new forms of RNA and DNA during embryogenesis. Mating does not induce the formation of new forms of RNA and DNA in the ovaries but does stimulate synthesis of rRNA and maturation of the oöcyctes.

CHANGES IN TRANSFER RNA PATTERNS DURING THE DEVELOPMENT OF *DROSOPHILA MELANOGASTER*

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Transfer RNA has been extracted and purified from *Drosophila melanogaster* at 14 different stages of development. The amino acid acceptor activity of each preparation has been determined *in vitro* using 14 different ^{14}C-amino acids. The total acceptor activity (mμmoles of aminoacyl-tRNA formed per mg tRNA) changes during the life cycle, falling during life in the puparium to about 60% of the level found in late third instar larvae or adults. The tRNA pattern (acceptor activity for the individual amino acids) also changes markedly during life in the puparium; there is clearly a pupal pattern characterised by relatively high levels for glutamic acid, phenylalanine and serine, and an adult pattern characterised by relatively high levels for leucine and valine. In fact for six amino acids, acceptor activity falls markedly (2-5 fold) at emergence whereas for seven, acceptor activity rises markedly.

The magnitude of the changes illustrates the potentiality for tRNA-mediated translational control of protein synthesis during dipteran development.

STUDIES OF THE SYNTHESIS OF MITOCHONDRIAL PROTEINS IN *LUCILIA* (DIPTERA: CALLIPHORIDAE)

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There are two periods of rapid mitochondrial development during the life-cycle of the blowfly, *Lucilia cuprina*. These are early in the third instar of the larva, and during flight muscle development in the period spanning emergence of the fly. Protein synthesis by mitochondria isolated from insects at these two stages has been studied and the temporal relationship to the appearance of mitochondrial enzymes defined. In addition the rate of synthesis of the mitochondrial protein cytochrome c *in vivo* during flight muscle development has also been measured.

Using the results of these studies and published data the significance of mitochondrial protein synthesis in the development of these organelles will be discussed.

SOLUBLE PROTEIN SYNTHESIS DURING THE ADULT DEVELOPMENT OF *LUCILIA* (DIPTERA: CALLIPHORIDAE)

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The rapid formation of glycolytic enzymes over the period of emergence is an important feature of the development of the capacity for energy transformation in the thoracic flight muscle. Of particular importance is cytoplasmic α-glycerophosphate dehydrogenase, which links extra-mitochondrial oxidation of glycolytically produced NADH with the energy producing mitochondrial oxidation of α-glycerophosphate.

During the day spanning emergence, the total activity of this enzyme increases nine-fold; after emergence enzyme levels are higher in females than males. This dramatic appearance of enzyme activity can be related to the ability of the insect to fly shortly after emergence.

Labelled amino acids injected into the total body pool can be incorporated into the enzyme *in vivo*. Both this incorporation and the appearance of enzyme activity are inhibited by cycloheximide, indicating that the enzyme is synthesized *de novo*. Such synthesis can also be correlated with other structural and biochemical changes occurring in the thorax over this period.

THE OMMOCHROME BIOSYNTHETIC PATHWAY OF *DROSOPHILA MELANOGASTER:* VARIATIONS IN THE LEVELS OF ENZYMES AND INTERMEDIATES DURING DEVELOPMENT

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The onset of eye pigmentation in *Drosophila melanogaster* is under precise developmental control as demonstrated by its appearance at a defined stage of adult development. Xanthommatin synthesis begins 48 hours after pupation and its accumulation continues until about 24 hours after eclosion of the adult. The increase in amount of ommochrome coincides with the disappearance of its two immediate precursors, 3-hydroxykynurenine and kynurenine. In addition, variations in the levels of these intermediates correlates with the activities of the two enzymes responsible for their production, viz. kynurenine-3-hydroxylase (EC 1.14.1.2) and tryptophan pyrrolase (TP 1.13.1.12). Since both these enzymes are active before the commencement of pigmentation and substantial amounts of both their products are present well before that time, it is probable that neither is involved in controlling the onset of ommochrome synthesis. Control is most likely through the final enzyme which oxidatively condenses 3-hydroxykynurenine to xanthommatin.

SYNTHESIS OF CUTICLE PROTEINS DURING DEVELOPMENT OF THE COCKROACH

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Blood protein concentrations remain relatively constant during the ecdysial cycle in the American cockroach except during the immediate pre and post ecdysial periods. Blood volume also follows this pattern, showing a sharp rise during pre ecdysis and a drop after ecdysis. The major synthesis of haemolymph protein occurs during pre ecdysis as expected but new protein is synthesized and incorporated into the cuticle during post ecdysis and inter ecdysis as well.

During the pre ecdysial stage, the increased blood volume allows the circulation of many additional cells. Among these are fat body cells and a number of blood cells which are apparently undergoing cell division. Analysis of the haemolymph, fat body, midgut and epidermis at this time show that all four preparations are capable of synthesizing blood proteins which have the potential of becoming cuticle proteins.

INCORPORATION OF HAEMOLYMPH PROTEINS INTO THE CUTICLE OF THE COCKROACH

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Haemolymph proteins have been shown by previous investigations to be incorporated relatively unchanged into the cuticle. Immunodiffusion, double labelling with ^{3}H and ^{14}C, and cross absorption experiments suggest that a number of haemolymph proteins are potential precursors of cuticle components. These precursors apparently are present at all times during the life of the American cockroach.

During the pre ecdysial period, some of these haemolymph proteins polymerize and are incorporated into the new preforming cuticle. At the time of ecdysis, phenol bound proteins begin to be laid down within the same matrix and cross-linking occurs.

γ-GLUTAMYL TRANSPEPTIDASE ACTIVITY IN THE IMMATURE HOUSE FLY, *MUSCA DOMESTICA* L. (DIPTERA: MUSCIDAE), A HISTOCHEMICAL STUDY

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Histochemically observed changes in the activity of γ-glutamyl transpeptidase (γ-GTP) have been correlated with the physiological functions of the enzyme during the housefly life cycle. During larval growth, highly active γ-GTP is found on the brush border of the Malpighian tubule and midgut epithelial cells, where it catalyzes the formation of the dipeptide γ-L-glutamyl-L-phenylalanine. Activity in the midgut largely disappears by white puparium formation and the dipeptide is no longer synthesized. At this time, there is also an abrupt, ecdysone-induced appearance of γ-GTP activity on the epidermal cell membrane of the epidermis-cuticle interface. This activity, thought to be involved in the translocation of tanning substances into the puparium, disappears when puparium tanning is completed. By contrast, γ-GTP is not induced at this stage in the epidermis of the pseudocephalon. This head-region of the larva becomes invaginated during puparium formation and does not undergo tanning.

TANNING OF *TENEBRIO MOLITOR* L. (COL.: TENEBRIONIDAE) ADULTS: ROLE OF ABDOMINAL NEUROHAEMAL ORGANS IN THE RELEASE OF TANNING HORMONE

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The tanning process of the adult of *Tenebrio molitor* lasts about 10 days. It occurs in two steps: (1) Pre-ecdysial tanning: head, pronotum, legs and various setae; (2) post-ecdysial tanning: abdominal and thoracic sternites and elytra.

Ligatures at different levels and transections of the ventral nerve cord show that, after cephalic induction, a tanning factor similar to "bursicon" is released in the blood from abdominal neuromeres.

This substance induces the post-ecdysial tanning only, although the metabolic pathway of pre- and post-ecdysial tanning seems identical.

The blood becomes active during the two last days of the pupal stage, and some activity remains in the young adult (about 24 hours). Compared with the cases of *Sarcophaga* and *Periplaneta*, the timing of these events in *Tenebrio* is different, mainly concerning the cephalic induction and the release of the hormone.

In an attempt to specify the exact location of bursicon release, ganglia and nerves of 6 day old pupae have been injected into ligated pupae one day before imaginal ecdysis.

The first series of experiments shows that:

1. The last abdominal ganglion and its nerves do not induce post-ecdysial tanning.
2. The lateral nerves of anterior abdominal ganglia induce post-ecdysial tanning. These nerves bear neurohaemal organs which are believed to stock and release the tanning hormone.

CHAIN CHARACTERS OF PUPARIAL CHITIN

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Oxidation of sarcophagid puparial cases with N-bromosuccinimide affords amino acid-substituted peptidochitodextrins depleted of aryl residues. Interchain forces resist disruption in guanidinium, detergents, salt solutions, dilute alkali or reducing media. Dispersal is effected rapidly in cold 6 M mineral acid yielding paucidisperse soluble fragments of 1200 and 1600 daltons. Generation of limit dextins from the NBS-product with chitinase and proteases provides a water-insoluble core residue and a dialyzable portion of lower molecular weight. The insoluble material can be taken up in 15 M formic acid for exclusion chromatography yielding a fraction of about 40,000 molecular weight; mole ratio N-acetylglucosamine : glutamic acid : glycine : aspartic acid : threonine : serine : alanine 260:2:2:1:1:1 . The dialyzable dextrins include peptidylated oligosaccharides, pI 3-4 with high affinities for anion exchangers and a predominance of acetylglucosamine, glutamic and aspartic acids.

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METABOLISM OF AROMATIC AMINES IN THE COCKROACH

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The metabolism of ^{14}C dopamine and ^{14}C noradrenalin has been studied and correlated in the American cockroach. The evidence obtained indicates beta-hydroxylation does not appear to be a major metabolic pathway, accordingly two aromatic glucosides, one acidic and one neutral, have been found and tentatively identified using radioisotope techniques. Subsequent work has shown both glucosides capable of becoming loosely bound to a small protein. The reinjection of this labelled protein results in the incorporation of the label into larger haemolymph proteins and the cuticle. Recent studies have also shown ^{14}C-dopamine to be metabolized to a glucoside in the tobacco hornworm. Subsequently it was demonstrated that several different proteins pick up the aromatic label and transfer it (or become incorporated) into the cuticle. The significance and possible identification of these carrier proteins will be discussed in terms of cuticle tanning.

OCCURENCE OF PHENOLS IN THE VENTRAL GLANDS OF THE AMERICAN COCKROACH, *PERIPLANETA AMERICANA* L.

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It has been known that the adult American cockroach possesses a pair of ventral glands between sixth and seventh sterna which are probably used as a means of defense against predators.

The glands secrete clear liquid with strong odour mostly when they are seized at the body. The secretion was collected with capillaries or filter papers and extracted with ether. The amount of secretion per head is about 0.5 mg but gives 0.05 mg of ether soluble material.

Chemical analysis of the ether soluble part was mainly conducted by GLC and MS. The main peaks on GLC were all alkali-soluble. They were confirmed as phenol, cresols and xylenols by GLC and MS. The analysis of extracts of feces and papers taken from cockroach-rearing containers revealed the presence of phenols.

Since phenols are known to be strong disinfectants, the secretion also functions as protective substance against germs.

STRUCTURE-FUNCTION RELATIONSHIPS IN THE ENDOCRINE SYSTEM

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The functional interpretation of endocrine activities and their neural control in insects gains much from cytophysiological studies at the ultrastructural level. Recent advances concern the sites of synthesis, storage, release, and transport of both neural and non-neural chemical mediators. Proteinaceous neurohormones can be traced from the perikarya of neurosecretory neurons to axonal sites of discharge ("synaptoids"). The detection, in the corpus allatum of some insects, of a distinctive cellular product (C body material) may be correlated with the manufacture of juvenile hormone, a nonproteinaceous mediator. Depending on their extracellular pathways, neurosecretory substances function either as neurohormones (distribution to effector organs via the circulation), or as chemical messengers which, like neurotransmitters, have a highly localized site of action (release in close proximity to effector cells).

Perhaps the most pertinent insights gained from these studies are (a) the multitude of existing types of signals, and (b) the close interdependence between the neural and the endocrine systems of integration.

RNA SYNTHESIS DURING SILKMOTH OOGENESIS

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Trophic cells in the ovarian follicles of *H. cecropia* and *A. polyphemus* (Lept.) synthesize large amounts of RNA which is transported into the developing oocytes via ring canals. A large proportion of this RNA is represented by ribosomes and the isolated nuclei of the trophic cells are very favorable material in which to study the kinetics of synthesis, assembly, and processing of ribosomal subunits. A second prominent product of the nuclei is smaller ribonucleoprotein particles which are transported from the trophic cells into the oocytes, and which can be extracted from the cortical region of the oocyte. The fine structure of the nurse cells exhibits many unusual features in addition to large numbers of free cytoplasmic ribosomes. The cytoplasm also contains a large number of much smaller particles and bundles of microtubules which may form a supporting substructure as well as mediating the movement of various formed cytoplasmic elements. The nuclei contain a variety of nucleolar elements as well as fibrous structures associated with nuclear pores.

SYNTHESIS AND DEVELOPMENT OF COLLAGENOUS TISSUES

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Collagen occurs in the internal supporting tissues of insects, together with certain protein-polysaccharide complexes, the glycosaminoglycans, chondroitin and keratin sulphates. These tissues are usually confined to thin layers surrounding and thus supporting the internal organs. They are secreted in the latter stages of the development of the organs.

Since the collagenous tissues are formed at specific times, it has been possible to trace the development of both the collagen and the associated glycosaminoglycans. Studies of H^3-proline uptake by insect fibroblasts have elucidated the intracellular pathway of collagen synthesis; the collagen is synthesised by the rough endoplasmic reticulum and it then passes into the matrix where fibril formation occurs. The glycosaminoglycans are synthesised at the same time; there are changes in these substances as the collagen ages comparable with those found in vertebrate connective tissues.

FINE STRUCTURE OF THE DIAPAUSE AND DEVELOPING SILKMOTH OVARIOLE SHEATH

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During adult development the silkmoth ovariole undergoes striking morphological changes which involve not only the follicular oocyte-nurse cell complexes but also the outer and inner (intermediate layer) ovariole sheaths. The diapause sheath consists of 8 to 12 layers of elongate cells joined by desmosomes and containing some mitochondria, some vesicular smooth endoplasmic reticulum, and many free ribosomes. The nuclear membrane is studded with ribosomes, but rough endoplasmic reticulum and Golgi membranes are scarce. Some cells contain large numbers of microtubules.

As development proceeds, large spaces separate the cells, the number of layers is reduced, and myofilaments appear in some cells. Cisternal rough endoplasmic reticulum, Golgi membranes, and mitochondria are frequent, and lysosomes and residual bodies are seen.

The loose intermediate layer cells also show marked changes with respect to endoplasmic reticulum morphology, mitochondrial density, lysosome and dense granule appearance, and plasma membrane activity associated with vesicle formation.

REGENERATION IN ADULT *BLATTELLA GERMANICA* (L.) (DICTYOPTERA: BLATTELLIDAE)

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Stumps within which regenerates develop after metamorphosis occur very rarely in *Blattella germanica* after post-critical autotomy of a metathoracic leg during the final (6th) nymphal instar. Post-critical amputation of the distal third of the coxa yields up to 15% of such "activated" stumps.

Precritical autotomy invariably yields external regenerates. Precritical amputation yields 40-50% external regenerates, 50-60% stumps in which regeneration begins only *after* metamorphosis. Imperfectly formed external regenerates from amputations autotomise spontaneously soon after metamorphosis; regeneration occurs subsequently in about 80% of stumps so formed. Neither autotomy nor amputation of adult metathoracic legs, even immediately after metamorphosis, has yet been shown to induce any regeneration.

Similar results arise from inducing autotomy of the contralateral leg 3 days after amputation, or simultaneously with *precritical* amputation. Contralateral autotomy simultaneous with *post-critical* amputation apparently induces interactions between the stumps and may increase the frequency of activation.

Post-critical amputations yielded more consistent results and higher ratios of activated stumps in females than males. Similarly, post-critical females were more affected than males by farnesyl methyl ether applied to the wound at the time of autotomy or amputation.

The significance of these results and other work still in progress will be discussed in relation to some models of the control of insect development.

EFFECTS OF ECDYSONE ON THE DEVELOPMENT OF IMAGINAL DISKS IN *SARCOPHAGA PEREGRINA*

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A moulting hormone, ecdysone, provokes pupariation and subsequent true pupation in the mature larvae of *Sarcophaga peregrina.*

Actinomycin D stops pupariation and pupation with or without exogenous ecdysone. When Actinomycin D is given 5 hr after the injection of ecdysone, pupariation takes place almost normally, meaning that the action of ecdysone for pupariation is completed within 5 hr. DNA synthesis-inhibitors do not prevent pupariation, but do prevent pupation. Synthesis *de novo* of DNA in the imaginal disks increases drastically 12 hr after the initiation of ecdysone secretion, and isolated abdomens can pupate if the ligature is applied after 12 hr.

Stimulative activity of ecdysone on DNA and RNA synthesis in imaginal disks *in vitro* is almost similar to those *in vivo.*

From these results, a possible mode of action of ecdysone will be discussed.

MICROTUBULES AND TRACHEAL MIGRATION IN WING DISKS CULTURED *IN VITRO*

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Wing disks from the last larval instar of *Galleria mellonella* (L.) (Lepidoptera: Galleriidae) may be cultured *in vitro* in Grace's tissue culture medium (without haemolymph), a chemically defined medium. Alpha-ecdysone (3 μg/ml) induces tracheal (tracheolar) migration into the lacunae of such disks. This tracheal migration is prevented by colchicine (10^{-3}M) or vinblastin (10^{-8}M), known inhibitors of microtubule formation.

Large numbers of microtubules are found in the tracheal and tracheolar cells. The long axis of these microtubules is parallel to the long axis of the tracheae. Microtubules were not observed after colchicine or vinblastin treatment. We conclude from this evidence that one requirement for tracheal migration in wing disks may be the presence of oriented microtubules.

RETROGRESSIVE DEVELOPMENT IN *TROGODERMA GLABRUM*

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Larvae of *Trogoderma glabrum* are capable of surviving long periods without food or water. During this period, ecdyses occur regularly, with post-ecdysis larvae being smaller and lighter in weight than the pre-ecdysis forms. The rate of weight-loss is very low during retrogression, and is accompanied by a 95% suppression of oxygen uptake. Retrogressed larvae will resume normal growth immediately upon access to adequate food. Regrown female larvae may undergo from two to several ecdyses with increase in size and weight, but without metamorphosis unless a number of pupation-inducing factors are operative: (1) adequate space; (2) adequate population density; (3) males of the species; and (4) long-day photoperiods. Physiological regulation of retrogression and regrowth has been studied. During retrogression, the repeated ecdyses are juvenile because of continued activity of the corpora allata. Similarly, pupation of regrown larvae is apparently prevented, in the absence of the factors listed above, because of the continued domination of juvenile hormone.

THE WORKER CASTES OF THE HODOTERMITID HARVESTER TERMITES

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Hodotermes, *Microhodotermes* and *Anacanthotermes* have two worker castes, unpigmented "housekeepers" or larvae, and "foragers", workers proper, which are pigmented in *Hodotermes* and *Microhodotermes*. The foragers are of two types, major and minor.

In *Hodotermes* the major and minor foragers develop from different larval stages; minors do not moult to majors. For each major worker there are approximately 3.7 minor workers, and the actual sizes of the two forager castes varies from colony to colony. The first pigmented worker in incipient colonies is a 4th instar minor worker, but in mature colonies the first worker instars are later and variable. Large larvae, which can produce major workers, and small larvae with patchy pigmentation, which can produce minor workers, can undergo stationary moults, as can the foragers themselves.

The unpigmented larvae are equivalent to the pseudergates of other lower termites, and the foragers are a developmental stage unique to the hodotermitids.

THE EXISTENCE OF THREE POLYNUCLEOTIDE CHAINS IN 26S RIBOSOMAL RNA FROM CULTURED *AEDES AEGYPTI* CELLS

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Ribosomal RNA was co-extracted from a mixture of labelled BHK cells and unlabelled *Aedes aegypti* cells. On heating at 60°C for 5 min in 0.1M NaCl, 0.01M sodium acetate (pH 5), the 26S *Aedes* RNA, but not the 28S BHK RNA, specifically separates into two major polynucleotides of molecular weight near 0.7×10^6. The large rRNA from all insects examined (from 9 different orders) shows this property except that from two species of aphid. The region of stabilization has properties distinguishing it from the "average" helix in 26S rRNA. Associated with the *A. aegypti* 26S species is a '7S RNA' which is released on mild heating. There are three 3'-termini per 26S species as shown by labelling periodateoxidized RNA with $[H^3]$-iso-nicotinic acid hydrazide (INH). T_1-RNAse treatment of INH-labelled RNA gives three unique labelled oligonucleotides confirming the existence of three polynucleotide chains and showing that the "central" scission is at a specific base sequence. The introduction of the scission occurs after formation of 26S RNA from the 30S RNA precursor.

ENZYMES IN TISSUES OF SILKWORM DURING ONTOGENESIS

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The quantity and enzymatic activity of soluble proteins of silkworm in process of development from egg to moth is studied after polyacrylamide gel microelectrophoresis. It was shown that the number of protein fractions varied from 16 to 32. The number of protein zones decreases during the moult of larva and increases when larva turns to pupa.

Glutamate dehydrogenase, alanine dehydrogenase, diphenoloxidase, acid phosphatase, alkali phosphatase and esterase are established in observed protein fractions. From 2 to 11 forms of enzymes are associated with protein zones on the columns. Some of the protein zone complicates fermentative activities. The number of the forms of these enzymes correlates with the physiological and biochemical processes in the organism of silkworm during the period of ontogenesis.

The effects of some agents (SDS, monochloracetic acid, p-chlormercuribenzoate, hydrazine, hydroxylamine, phenylalanine, NaF, $CuSO_4$ etc.) on the activities of enzymes were studied. The sensitivity of enzymes to these agents depends on the stage of development of the silkworm.

CHANGES IN TREHALOSE CONCENTRATION AND OXYGEN CONSUMPTION DURING THE METAMORPHOSIS OF THE RICE STEM BORER, *CHILO SUPPRESSALIS* WALKER

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Changes in the trehalose concentration in the haemolymph and in the oxidation of respiratory substrate at various developmental stages in the rice stem borer, *Chilo suppressalis* Walker were measured using gas chromatography (pyrolyzed furnace method) and Warburgs manometric method, respectively.

The haemolymph trehalose concentration decreased gradually until the four day pupa and increased at the six day pupa. In the last instar larval stage and newly emerged adult stage the concentration reached a maximum.

Endogenous respiration was very high at the two day pupal stage, decreasing at six day pupa, followed by an increase at the late pupal stages.

Succinate in the respiratory substrate increased respiratory activity in all stages and had striking influence on both the late pupal stage and adult.

The changes in the trehalose concentration and the rate of oxygen consumption through the course of life cycle, form a U-shaped curve when graphed corresponding to the histogenesis of adult organs and histolysis of larval organs.

From a control point of view, the U-shaped curve of physiological activity indicates that control will be most effective at the time of physiological weakness during the four day pupal stages.

UTILIZATION OF THE METHYL GROUP OF METHIONINE BY *MUSCA DOMESTICA* LARVAE

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The methyl group of ^{14}C-labelled dietary methionine is not incorporated into choline by housefly larvae that are reared axenically. The methyl group is incorporated into serine and ethanolamine and into the neutral lipid fraction. The methyl group is also incorporated into RNA. In the presence of dietary adenosine and uridine, ^{14}C incorporation into the heterocyclic bases was suppressed, and labelling of 2'-O-methyl-adenosine, -uridine, -cytidine, and -guanosine was demonstrated.

EFFECT OF FOLIC ACID ANTIMETABOLITE (AMINOPTERIN) ON THE GROWTH AND METAMORPHOSIS OF *ORYZAEPHILUS MERCATOR* (FAUV.) LARVAE

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The present experiments were carried out to determine the effect of aminopterin on the growth and development of the larvae of *Oryzaephilus mercator* to establish whether the folic acid is a dispensable or indispensable vitamin for this insect. In an earlier report the folic acid was shown to be a dispensable vitamin for this insect which is unlike most of the insects because almost all of them have a definite need for it. Probably this insect obtains it by some other source, maybe from symbionts or as a nutrient reserve transferred from the adult to egg or as a contaminant in the casein. Aminopterin, a folic acid antagonist, is capable of completely blocking the activity of folic acid reductase thereby confirming the necessity of folic acid. Thus by employing it, it is confirmed that *O. mercator* has a definite need for folic acid and its deficiency leads to adverse effects on survival and the rate of growth.

CARBOHYDRATE METABOLISM IN THE NERVOUS TISSUES OF THE DESERT LOCUST, *SCHISTOCERCA GREGARIA*

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Evidence demonstrating the occurrence of some of the glycolytic enzymes in the nervous tissues of desert locust *Schistocerca gregaria* has been obtained. The glycolitic pathway in nervous tissue appears to be similar to Embden-Meyerhof type described for other organisms.

The enzymes shown to be present in the nervous tissue are, hexokinase (E.C., 2.7.1.1.), glucose phosphate isomerase (E.C., 5.3.1.9), triosephosphate dehydrogenase (E.C., 1.2.1.9), glycerol-3-phosphate dehydrogenase (E.C., 1.1.1.8) and lactate dehydrogenase (E.C., 1.1.1.27). The activity of lactate dehydrogenase was found to be nearly equal to that of glycerol-3-phosphate dehydrogenase.

QUALITATIVE ANALYSIS OF FREE AMINO ACIDS IN THE DEVELOPMENTAL STAGES OF *LASIODERMA SERRICORNE* F. BY THIN LAYER CHROMATOGRAPHY

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A qualitative analysis of free amino acids was done by thin layer chromatography in different developmental stages, eggs, first to sixth instars, prepupa, male and female pupae, and adults both male and female of *Lasioderma serricorne*.

Lysine, histidine, hydroxyproline, proline, glutamic acid, valine, and tyrosine were detected in all stages; cystine, arginine, serine, glycine threonine, leucine/isoleucine, tryptophan, aspartic acid, alanine, and phenylalanine were present in some, but not all stages. These results are discussed in relation to metabolism during development.

EGG PRODUCTION, OVIPOSITION, AND SURVIVAL OF ISOLATED QUEEN HONEY BEES FED EXPERIMENTAL DIETS

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Fertile egg-laying queen honey bees, *Apis mellifera* L., removed from the colonies and isolated on experimental diets continued to expel eggs for only 48 hours, and none of the diets stimulated them to resume egg laying. When such queens were isolated and fed 5 days by small numbers (15) of 15-day-old nurse bees feeding on experimental diets, the subsequent autopsy revealed neither eggs in their oviducts nor ovulable-size eggs in their ovaries. However, when queens in screenwire push-in cages were introduced into larger cages containing 300 workers of known age, and the attendants were fed 2.5% pollen in dextrose-levulose syrup (and water), the autopsied queens contained eggs after 2 or 5 days of such treatment.

Isolated queens lived significantly longer on diets of dextrose-levulose syrup, queen candy, or egg albumin than on fresh royal jelly, frozen royal jelly in dextrose-levulose syrup, or pollen in a carbohydrate mix.

THE ROLE OF YEASTLIKE ENDOSYMBIONTS OF THE ANOBIIDAE (COLEOPTERA) IN THE PROTEIN METABOLISM OF THE HOST

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The endosymbionts of the Anobiidae are commonly considered as sources of vitamins for their host. Low protein concentrations are by far more characteristic for substrates attacked by Anobiidae than an insufficient supply with vitamins. The endosymbionts are part of a feed-back system; they assimilate the excretion products of their hosts and excrete amino acids which are utilized by the larva. In protein deficient diets uric acid and some amino acids proved to be good additional nitrogen sources for normal larvae; aposymbiotic larvae did not react or were inhibited. A complete vitamin mixture promotes the growth even of normal larvae to such an extent that a supply of vitamins cannot play any important role in protein deficient diets.

SECTION NO. 6

ECOLOGY

CONVENOR: T.O. BROWNING

COMPARISON OF GROUND SURFACE SPIDERS IN FOUR CENTRAL FLORIDA ECOTONES

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A three and one-half year study of spider populations on the surface of sand pine dunes, pine flat-woods, citrus groves, and residential areas in central Florida utilizing can-traps has been carried out. Twenty-three prevalent species in six main families produced a distinctive population in each ecotone. The sand pine dune population was 53% lycosid, 19% gnaphosid and 18% salticid; the pine flat-woods 64% lycosid, 21% salticid, and 5% linyphiid; the residential area 54% lycosid, 23% theridiid, and 16% linyphiid; and the citrus grove 38% clubionid, 19% theridiid, 18% lycosid and 11% linyphiid. The citrus grove population was also only one-third as dense as those of the other ecotones. Most of the differences among the populations of the sand pine dunes, pine flat-woods and residential areas seemed to be the result of ecologically-equivalent species replacement but the strikingly different citrus grove population apparently was the result of repeated disturbance of the soil surface during cultivation.

DESERT POND COMMUNITIES AS INFLUENCED BY BIOLOGICAL AND CHEMICAL MOSQUITO CONTROLS

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In the Lower Sonoran desert of California 32 experimental ponds were subjected to mosquito suppression techniques (1968-1971). These were fenthion, *Gambusia affinis*, fenthion and *G. affinis* combined and Flit MLO.

Life tables and survivorship curves were constructed for subimaginals of *Culex tarsalis* (encephalitis vector) and *Culiseta inornata*. Population dynamics of the predators (especially Dytiscidae and Libellulidae) were analyzed.

In the fenthion regimen the pupae of *C. tarsalis* continued development unaffected and mosquito and predator resurgences and overshoots were recorded.

In the *G. affinis* regimen selective predation was noted with a resultant initial increase in mosquito emergence. Algal blooms were attributed to predation upon herbivores.

In the combined regimen pupae continued development and algal blooms occurred.

In the Flit MLO regimen the pupae were all killed. A resurgence occurred without an overshoot since a viable predator population was maintained. The phenomena of "prey switching" occurred.

CLASSIFICATION AND ORDINATION OF COMMUNITIES AT DIFFERENT TROPHIC LEVELS

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Methods of classification and ordination have been used to analyse the distribution of the species found in a food web with three trophic levels - plants, molluscs and sciomyzid flies. The data were obtained from fifty sites in five study areas in Anglesey, North Wales.

Similarity analysis of the five study areas based on abundance data, and association-analysis and principal component analysis of the fifty sites based on presence-absence data gave ecologically interpretable results. The analyses based on sciomyzid or mollusc or plant data considered separately or together show a clear distinction between two lakeside and three wet dune slack communities. On the basis

of the plant data, the two lakeside communities are also distinct from each other, but the mollusc and sciomyzid species found in them are similar. In almost all analyses, the dune slack sites form an intergrading series, with considerable differences between sites at the extremes, but no clear subdivisions within the series. These results will be related to the ecology of the plants and animals concerned. The usefulness of classification and ordination procedures in studies of animal communities and trophic relationships will be discussed.

ECOLOGICAL NICHES IN TWO COMMUNITIES OF ADULT ODONATA

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Field research carried on during three years tried to demonstrate the validity of the principle of competitive exclusion in two adult dragonflies communities. The 15 species found to be regularly present and breeding at two natural ponds near Rome, Italy, were checked by the following ecological features: seasonal periodicity, diurnal periodicity, site of mating pair formation, site and modality of oviposition, territoriality. The best ecological differences were found concerning the first, third and fourth of these features. Combining them it was found that no two species have the same ecological niche, except that the three *Sympetrum*-species could not be thoroughly investigated. It was also found that the existence of different sites of pair formation works as a pre-mating mechanism for interspecific reproductive isolation between *Coenagrion puella* and *C. scitulum* and seems to exist together with mechanical solution.

STABILITY VERSUS COMPLEXITY IN MODEL ECOSYSTEMS

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We survey an assortment of new theoretical models, all bearing on the question of population stability in multi-species communities. Overall, this review is directed at the field and laboratory ecologist, and aims to be interpretive and non-mathematical.

The main conclusion, derived from several independent lines of argument, is that in general multi-species mathematical models, increased complexity tends to diminish rather than enhance stability. Although stability and complexity may go together in the real world, such stability must be the result of quite special strategies, and is not a mathematical consequence of complexity *per se*.

THE ECOLOGY OF *ACACIA* CECIDOZOA

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Flower buds and young foliage of *Acacia baileyana* are galled by a complex of six cecidozoa: Pteromalidae (2), Eulophidae, Cecidomyiidae (2), (insects) and Eriophyiidae (Acarina). These in turn support a complex of inquilines and parasites. One pteromalid and one cecidomyiid are restricted to flower buds; the other pteriomalid and the eulophid occur on flower buds and foliage; the other cecidomyiid on developing pods and the eriophyiid on leaves. Similar galls also occur on related acacias. Around Melbourne the pteromalid *Trichilogaster* is dominant while the cecidomyiid flower gall is dominant around Cootamundra, N.S.W. (the natural range of *A. baileyana*). The comparative phenology of insects and *Acacia* has been investigated. Effects of stand age, relative dispersal and fecundity of the cecidozoa are discussed in relation to field findings of their relative abundance. The effect on the plant of this diversified attack has been investigated and possible competitive interactions are discussed.

A STUDY OF INSECT POPULATIONS OF TWO DIFFERENT NORTH AMERICAN DESERT PLANT COMMUNITIES AND FACTORS INFLUENCING DENSITY

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For several years investigations of insect densities have been undertaken in several selected desert plant communities of western North America. The Larrea-Franseria communities of the International Biological Program's Desert Biome validation site at Rock Valley, Nevada and the Joshua Tree National Monument, California; the Pinyon-Juniper communities of the Spring Mountains, Nevada and the Joshua Tree National Monument have been examined. The study sites in Nevada and California are separated by about 300 miles and their plant composition is slightly influenced by the different deserts to the north and south of the Nevada and California sites respectively. Precise sampling programmes were followed to assure uniform sampling of the populations. Climatic data were gathered on a broad term basis and during each sampling period. Live and dry weights, seasonal density and biomass were estimated. Significantly lower densities, lower dry weights and smaller biomasses were found in the Nevada plant communities.

BURIAL OF COW AND BUFFALO DUNG BY LARGE SCARABAEID BEETLES IN RHODESIA

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Pachylomera femoralis and two species of *Heliocopris* remove more than 90% of all buffalo dung deposited during the wet season in Wankie National Park, Rhodesia. *Pachylomera* is active by day, and *Heliocopris* by night. At dawn, individuals fight over dung. Smaller scarabaeids are also present. *Pachylomera* rolls dung away as small balls until they stick against an obstruction (branch, tussock, hoof print), whereupon they are buried 3 to 6 cm below the surface. After eating some of this dung, the adult beetle abandons the residue 24 hours later. *Heliocopris* buries a large mass of dung 0.5 to 2.0 m below the point of deposition, and this is used for oviposition. Nutrients and organic matter are redistributed to grass tussocks by *Pachylomera,* while *Heliocopris* has a major role in soil aeration and turnover. Both beetles reduce the availability of dung for oviposition by Diptera.

THE ECOLOGICAL AND GEOGRAPHICAL PECULIARITIES OF THE FLEA FAUNA (SIPHONAPTERA) OF THE UKRAINE

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In the Ukrainian SSR 104 species and subspecies of fleas were revealed. Ecological conditions of the country - forest and steppe - determine the presence here of the two rather distinctly separated complexes of Siphonaptera. The flea fauna of the Ukrainian forest zone (Woodlands zoogeographical province) is represented mainly by boreal species, widely distributed in the forest zone of Europe and Siberia.

The flea fauna of the steppe zone (Steppe zoogeographical province) of the Ukrainian SSR is basically characterized by the complex of steppe - and semi-desert fleas, inhabiting susliks, mole-rats, jerobas, marmots and some other rodents. There are here also representatives of the forest-flea complex which inhabit river valley, woods, and even meadow biotopes.

The forest-steppe (transitional) zone combines characteristics of both forest and steppe zones with few specific features.

The Siphonaptera of each of the three Ukrainian zoogeographical districts (Azov-Black Sea, Carpathian, and Crimean mountain districts) have also some peculiarities. These peculiarities are more clearly marked in the Carpathian mountain chain inhabited by endemic forms of fleas, such as *Ctenophthalmus obtusus, C. bychowskyi, Palaeopsylla steini,* and *Rhadinopsylla mesa mentschuli.*

Most of the Ukrainian Siphonaptera are palearctic forms, but there are 10 holarctic and 6 cosmopolitan species known. The flea fauna of the Ukraine reveals clear relationships with the Asia Minor-Balkan and Mediterranean faunas (genus *Stenoponia,* Subgenera *Spalacoctenophthalmus, Citellophilus* etc.). It shows also signs of an ancient tie to the Ethiopian fauna.

STUDIES ON THE ECOLOGICAL GENETICS OF NATURAL AND LABORATORY POPULATIONS OF *AEDES AEGYPTI* (DIPTERA: CULICIDAE)

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Control programs require ecological and genetical data on natural and laboratory populations. Studies on the fitness of hybrids and mutant strains are badly needed. Research on the effect of environmental and population components on fitness is also very important.

Observations concerning different components of *Aedes aegypti* life history were conducted. Data on several natural populations, inbred strains and their hybrids and on the yellow-larva mutant were integrated by the Life-Table Method. In addition, the effects of the reduction of genetic variability and colonization over five generations were studied. Finally, the effect of different temperatures and larval densities was also analyzed.

In all experiments information on longevity, time of larval and pupal development, egg production, mortality in immature stages, sex-ratio and hatchability was processed by computer program. Values for the mean life expectancy, R_0 and r were calculated in all the experiments.

ECOLOGICAL ENERGETICS OF A POPULATION OF THE GRASSHOPPER *POECILOCERUS PICTUS*

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and T.J. Pandian
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Fortnightly estimates of the numbers (by directly counting) and biomass of a population of *Poecilocerus pictus* during the year 1971 were made in a protected area (5,600 m^2 with 150 milkweed *Calotropis gigantea*, on which the insect completes its life cycle) near Bangalore airport. Individuals hatch during March-April, and after undergoing 6 moults emerge as adults by August, reproduce during September-October and die by early December. Numbers increased from 3.3 individuals per plant in early March to 22.7 and 19.4 individuals per plant in the middle of April and June respectively; subsequently they progressively decreased to 0.9 individuals per plant in late November. For the corresponding dates, the biomass values were 3.8, 53.3, 818.7 and 0.1 cal m^{-2}. Components of the energy budget are: production = 17.2 kcal m^{-2} $year^{-1}$, assimilation energy flow = 33.8 kcal m^{-2} $year^{-1}$, total energy consumption by the population = 102.3 kcal m^{-2} $year^{-1}$.

MECHANISMS OF MINERAL ACCUMULATION IN *MACROTERMES* MOUNDS IN AFRICA

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Mineral accumulation in *Macrotermes* mounds has been variously attributed to the use of sub-soil by termites, to evaporation from the soil, to the composition of fungus "comb" and of termites, and to differential leaching of the soil. In mounds in the Serengeti National Park a large volume of air flows through the mound, and the resultant evaporation leads to mineral accumulation. Faeces deposited on mounds by birds and mammals contain soluble mineral salts which are washed into the soil near the mounds, and subsequently concentrated by evaporation. Both mechanisms vary with the size of the mound. The mineral enrichment and the water relations of the mounds are the major factors which lead to the mounds having the dominant role in a biogenic spatial mosaic which affects species diversity.

ECOLOGICAL STUDIES ON THE ARTHROPOD FAUNA OF MAN-MADE HABITATS WITH SPECIAL REGARD TO SYNANTHROPY

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Studies were made of dumping-grounds, city parks and gravel pits. Most species of the dumps were confined to this habitat and had little similarity with the surrounding areas. More than 75% of the fauna originated from littoral habitats while forest and grassland elements were in the minority. However, differences between Finland, North- and South-Germany showed certain characteristic features due to the geographic region. Active life was observed to a depth of 70 cm and continued throughout the year. In city parks and human settlements more species from forests occurred than from the open land. This concerned ground-dwelling species as well as those nesting above the ground. Most insects from gravel pits were xerothermophilous. Many species of the 3 habitats have become synanthropic. In some cases this was followed by a change of behaviour. In Europe a clear tendency of increasing synanthropy from the south to the north was found.

SPECIFIC COMPOSITION AND DISTRIBUTION OF WIREWORMS (THE FAMILY ELATERIDAE) IN THE SOILS OF THE LITHUANIAN S.S.R.

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Investigations were carried out in soddy podzolic, soddy gleyish, soddy carbonate soils under cultivation, in boggy soils and in soils of natural habitats situated on the shores of the Baltic Sea.

In the abovementioned soils 22 species of wireworms were detected.

The highest number of wireworm species (16) was found in sandy soils of natural habitats near the Baltic Sea. The species *Prosternon tesselatum* had a wider distribution and occurred at an average of 2.4 specimens per square metre.

In soddy podzolic soils we found larvae of 11 species. Dominant were larvae of the genus *Agriotes*, the total number of which in soils under perennials reached 51 specimens/m^2.

In soddy gleyish soil wireworms of 5 species were detected. Dominant there were the larvae of *Agriotes lineatus* (on the average up to 14 specimens/m^2).

In soddy carbonate soil wireworms of 3 species were found, of which the most common was *Agriotes obscurus* (on the average up to 17 specimens/m^2).

In boggy soil the larvae of only one species, *Actenicerus sjaelandicus*, were discovered and they were scarce (0.2 specimens/m^2).

The composition of species and the densities of wireworms are influenced not only by different kinds of soil, climatic conditions and soil relief but also by the level of soil cultivation.

USE OF HEAVY ELEMENTS FOR MARKING INSECTS

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The need for a mark-release-recapture technique which allows for recognisably different marks is stressed in relation to the difficulty of handling large numbers of small insects. Heavy elements combined with fluorescent dust offer encouraging possibilities using alpha-particle bombardment as a means of analysis. The method is suitable for use in remote areas since samples of known recaptured insects can be stored indefinitely before analysis.

DISTINGUISHING SUBPOPULATIONS IN A CAPTURE-RECAPTURE STUDY

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Tests of capture-recapture assumptions and particularly of population homogeneity have been used to identify subpopulations within an alpine grasshopper community. In a study involving three species, three instars, two sexes, and a very variable vegetation and erosion mosaic, it has been necessary to distinguish all subpopulations which behave differently with respect to the capture-recapture model in order to avoid spurious lumping of data.

From extensive computation of four years of continuous data involving some 14,000 records of individually coded grasshoppers, the valid subpopulation groups of species, sexes and areas have been defined. Series of population estimates have been computed for each of these subpopulation groups and in turn these estimates related to feeding behaviour in order to determine grazing pressures. The unique coding of each animal has also afforded the necessary information on dispersal, longevity and phenology.

BIOENERGETICS OF THE GRASSHOPPER *POECILOCERUS PICTUS*

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and M.R. Delvi

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Energy budget of *Poecilocerus pictus* (from hatching to death) fed *ad libitum* on the milkweed *Calotropis gigantea* at 26 ± 2°C was estimated. A female and male grew to a maximum size of 5.1 ± 2.3 and 2.7 ± 1.8 g wet weight on the 236th and 218th day of life respectively. From hatching to death, a female consumed leaves containing 68.3 kcal and evacuated faeces containing 46.0 kcal; these values were 41.5 and 28.6 kcal for the male. Assimilation efficiency did not appreciably differ between male and female but decreased from 50.6% during the second instar to 28.8% during the last fortnight of adulthood; the efficiency over the complete life span in either sex averaged 32.9%. A male used 61% of the assimilated energy on respiration, 2% on reproduction and 5% on exuvia, whereas a female used only 38% on respiration, 14% on reproduction and 2% on exuvia.

COMPARATIVE PLAGUE DYNAMICS OF TROPICAL *LOCUSTA* (ACRIDIDAE)

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Plagues of tropical *Locusta* are comparatively infrequent events and are related to exceptional weather conditions. In some areas they recur in approximately ten year cycles, e.g. Madagascar and the Philippines, but in others, e.g. West Africa, they are noticeably rarer. In both West Africa and Madagascar outbreaks are associated with seasons of above average rainfall when exceptional multiplication occurs, although the actual courses of the outbreak differ due to the contrasting geography of the two regions. In the Philippines, on the other hand, outbreaks are associated with dry spells which induce unusually high levels of concentration, but since this area has a much higher rainfall than the others, multiplication is subsequently sufficient to lead to outbreaks. In all areas the survival of unusually high numbers during the dry season, when populations normally decrease, is an important feature of outbreaks. Factors which lead to an increase in breeding success during the dry season, such as irrigation, increase the chances of the development of gregarious behaviour and outbreaks in new areas.

FURTHER STUDIES ON THE BIOTIC THEORY OF LOCUST CYCLES

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The Biotic Theory of Locust Cycles was propounded by me several years ago, and a couple of papers have already been published. According to this theory the population explosion of the desert locust takes place in space and time not where and when the climatic component of the environment is optimum, as one would expect, but where and when it is actually very much sub-optimum (very high temperature and very low humidity); this is so because these climatic conditions are much more deleterious to the natural enemies of the locust. The present contribution reports the results of further studies by a team of workers whose names will appear in the full paper, on the food habits, biology, population density, etc. of the predatory fauna of the locust breeding areas and their surroundings, as additional observations and experiments in favour of the Biotic Theory.

INTRA- AND INTER-SPECIFIC COMPETITION BETWEEN SCIOMYZID LARVAE (DIPTERA)

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Laboratory experiments using the predatory malacophagous larvae of nine species of Sciomyzidae indicate that intraspecific competition results primarily in a decrease in the rate of development. There is little evidence for increased mortality. Larvae which have an initial advantage of size or weight keep or increase this advantage since they can kill snails more easily and obtain more food. They pupate sooner, but not at higher weights than slower-growing larvae. The efficiency with which the tissues of the snails killed is converted into larval tissue is reasonably constant for each species. The larvae tend to become more wasteful feeders near maturity.

There was little interaction between species, except when *Sepedon spinipes* (Scop.) was present. The growth of the larvae is related to the number of larvae present rather than their species. However, larvae of *S. spinipes* obtain a relatively greater proportion of the food than their competitors and lower the growth rate of the latter. Factors relating to success in interspecific competition will be discussed, and the experimental results related to conditions in the natural habitat of the species.

CONTRIBUTIONS TO THE ANALYSIS OF THE DYNAMICS OF POPULATIONS OF *HAPLODIPLOSIS EQUESTRIS* FABR. (DIPTERA: CECIDOMYIIDAE) AND ITS PARASITES

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The analysis of the population dynamics of *Haplodiplosis equestris* gives an explanation of its sudden mass incidence in Europe. The ecological associations of this gall midge include many abiotic and biotic factors to be discussed. In passing from wild gramineae biotopes to cereal crops *Haplodiplosis equestris* escapes from its main parasite (*Chrysocharis seiuncta* Del.). This explains the sweeping population growth. Owing to the biological superiority of *Chrysocharis seiuncta,* a further, hitherto unknown parasite (*Platygaster equestris* nov. spec.) is not "powerful" enough among wild gramineae to limit to any appreciable extent the population density of *Haplodiplosis equestris.* If there is no chemical control, however, this parasite becomes particularly active in the cereal crop biotope "recently conquered" by *Haplodiplosis equestris,* owing to the absence of its powerful antagonist. In the absence of chemical control, the second parasite soon reduces the population density of *Haplodiplosis equestris* in the cereal crop to an economically insignificant level which corresponds to its population density in wild gramineae biotopes.

POPULATION DYNAMICS OF GREENBUGS PARASITIZED BY *LYSIPHLEBUS TESTACEIPES*

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Lysiphlebus testaceipes readily attacks all ages of the greenbug and may "sting" one several times. Often the ovipositional thrust and/or "stinging" of the parasite was so forceful that the small aphids (1- to 3-days old) were knocked off the plant. Movement of sorghum greenbugs forced off the plant by *L. testaceipes* will be discussed. Aphids 4- to 5-days old in close proximity to a parasite frequently walked off or dropped from the plant. Greenbugs react promptly to a parasite female by pulling out their rostrum from the plant, running away and falling from the plant. An average of 40% of the total aphids crawled back to the plant and began feeding. Aphids of all ages "stung" three or more times and knocked off the plant usually died, thus reducing the number of mummies produced below the number of parasitized aphids.

NEW METHODS PROVIDE A RE-INTERPRETATION OF NICHOLSON'S BLOWFLY POPULATION 'OSCILLATIONS'

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Nicholson, in 1954, described violent population changes in blowflies given a small daily ration of food. In a separate experiment on competition he put different numbers of blowfly larvae with the same amount of food and demonstrated that with rising initial numbers the numbers of survivors first rose and then fell to zero. He termed this 'scramble' competition. Analytical methods developed from those of Ricker show that scramble competition of the kind observed provides a good explanation of the population changes, which were really alternations of large and small successive generations.

The blowfly oscillations arise from causes which are quite distinct from those involved in parasite-host oscillations discussed by Nicholson in 1933.

POPULATION STABILIZING MECHANISMS IN *CACTOBLASTIS CACTORUM* BERG (LEP. PHYCITIDAE)

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Cactoblastis cactorum was introduced into Australia to eat introduced pest prickly pears (chiefly *Opuntia inermis*). These two species now act as a stabilized two-element population-system. Other species (except man) have only a small influence on the system.

The moths stabilize both populations by clumping their eggs on some plants and temporarily sparing others. Clumping leads to population stability in *Cactoblastis* by starving the overcrowded larvae while the untouched and lightly loaded plants grow and provide a stabilized reservoir of food for the next generation of *Cactoblastis*.

Experiments and observations on population stability, dispersal, the behavioural basis of egg clumping and the influence of density on egg distribution will be described.

A COMPUTER POPULATION MODEL TO TEST MARK/RECAPTURE METHODS OF ESTIMATING POPULATIONS

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A computer population-simulator is described, in which a population of "animals" undergoes birth and death processes; random samples are drawn periodically, the animals given a date-specific mark, and released. Estimates of the population are made using different models - Petersen (=Lincoln Index), Schnabel, Bailey (Triple-Catch) and Jolly (Stochastic Model).

The experimenter may specify the initial size of the population, birth and death rates (and when they may occur), sample size, the probability of death while being marked the number of cycles of sampling required; also the number of independent replicates for the parameters stated.

An analysis of the estimation models based on their performance in the simulator is presented.

A COMPUTER SIMULATION MODEL FOR THE STUDY OF POPULATION DYNAMICS

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A discrete, stochastic computer simulation model is described which considers the interaction of birth and death rates, age distributions, and various types of density-dependent factors to produce a population growth form. With the appropriate density-dependent functions, the model reproduces the classical results for exponential and logistic growth. Any type of density-dependent (or density-independent) factors and their effects may be simulated, including those involving time-lags, changes in developmental rates, differential contributions and effects of the various age-classes, genotypes or life-stages, etc. The model may be modified easily and used by non-mathematicians to simulate (in theory, at least) the population dynamics of any organism. As an example, a modification specifically to simulate the growth of a laboratory population of *Tribolium* (Tenebrionidae, Coleoptera) is briefly discussed.

THE FREQUENCY DISTRIBUTION OF COLONY SIZE AS THE BASIC DATA IN THE POPULATION DYNAMICS OF THE ROSE APHID, *MACROSIPHUM ROSAE*

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The rose aphid, *Macrosiphum rosae*, is a pest that is found on plants of the family *Roseaceae* in many parts of the world.

In South Australia the species has been studied on hybrid tea roses, and on such roses the aphids occur in fairly discrete colonies on the new shoots or flower buds so that it is convenient to demarcate three different kinds of "population-system" that comprise: (i) the numbers of aphids on an individual rosebud; (ii) the numbers of aphids on all the rosebuds on a single rose plant; (iii) the numbers of aphids on all the rose plants in some arbitrarily defined space such as a particular rose garden, or the Adelaide metropolitan area, or the whole of the state of South Australia.

In theory, the processes of the simpler types of system can be separately studied and then integrated at the next level of complexity. And, in fact, the processes of systems of types (ii) and (iii) are explicable largely in terms of the processes that occur in the simplest of the three systems, namely aphids on a single rosebud.

The fate of colonies on single rosebuds depends on processes that are similar to those that have been described for other aphid species and may be summarized as follows: Once a colony of aphids has been started by an emigrant female or nymph (that becomes a female), the colony increases in numbers unless (a) catastrophic weather occurs, or (b) the quality of food for the aphid in the rosebud deteriorates (independently of the density of aphids), or (c) the colony is found by a predator or predators. If none of these limitations occur by the time the aphid numbers have reached a certain density, numerous "density-dependent" processes start to operate above different thresholds. The most important of these density-dependent processes that can eliminate or drastically reduce the numbers of aphids in a colony are (d) dispersal off the bud, by walking, of both nymphs and adults, and (e) the stimulation of wing development in the nymphs.

When the above data are considered, alternatively, as the numbers of aphids per rose plant, the same general trends are apparent but the relative influences of the five main processes discussed above are not nearly so obvious. And when the data are considered, alternatively again, as the number of aphids in the rose garden, the relative frequencies of the five main limiting processes and their influences are even further blurred.

So, in conclusion, it is suggested that for *M. rosae* the rosebud is the most useful population unit and that the population dynamics of *M. rosae* is better understood by using as basic data the frequency distribution of sizes of colonies of aphids and the changing frequencies of the main limiting processes that influence it, rather than by expressing the data as the mean number of aphids per rosebud, or the mean number of aphids per plant. In addition, with the data as a frequency distribution of sizes of colonies of aphids some estimate can be made of the opportunism exhibited by the species which colonizes a relatively transient resource, i.e. a rosebud.

LOCAL POPULATIONS

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In nature, local populations occur in almost infinite variety, but one fundamental division is possible: some populations are permanent (or at least perennial) while others are temporary. Permanent populations are those in which some individuals inhabit the local area at all times of the year. Temporary populations occupy a local area for only a limited part of each year.

It will be argued that the "dynamics" of temporary populations are basically different from those of permanent populations, and that the species involved tend to differ in some physiological as well as ecological respects.

Three case histories will be used to contrast the different types of populations. They show that an important key to the understanding of local populations is a thorough knowledge of the movements of the species concerned. We need to understand the different types of movements involved, what causes individuals to behave in a migratory or dispersive way, and what stimuli can cause them to abandon their dispersive movements in favour of "trivial" or "appetitive" movements and so form local populations.

Insects in permanent populations tend to have low capacities for dispersal (perhaps due to weak flying ability, wingless females, larvae not adapted for dispersal by wind, reduced dispersal by juvenile adults, etc.) whereas those from temporary populations tend to have high capacities for dispersal. They tend to be strong fliers, often with obligate juvenile dispersal, or with larvae adapted for wind-dispersal.

It will also be suggested that permanent populations are more likely to have evolved mechanisms which reduce the risk of over-exploitation of their environments. Thus they may have lower capacities for increase (lower fecundities or longer developmental periods), lower numbers (or densities) and fewer extreme fluctuations in the important population parameters. Species which form temporary populations, on the other hand, can be expected to have relatively high capacities for increase and generally increased ecological plasticity. They may also have fewer effective parasites and predators - especially obligate forms.

The implications of these ideas in relation to the concepts of unit and regional populations, as advanced by Maelzer and Hughes respectively, will be examined.

A FRAME OF REFERENCE FOR POPULATION STUDIES

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Insect ecologists are vaguely aware of differences between the population entities within the selected areas of habitats which, in practice, delimit their studies. In order to make meaningful comparisons, and, in particular, to see how far the conclusions of one study apply to another, it would be useful if each of them could be related to some generally applicable population concepts.

An ecologically defined, *evolutionary-unit-population,* within which the complete range of population adaptations of the species would develop, is probably the most obviously-useful entity with which to compare the population actually studied. Comparisons with other population concepts also may be helpful in communicating ideas. Examples suggested are (i) a *quantum-population*, defined as the largest normal grouping in which all the individuals concerned interact directly with each other, throughout a long period of their life cycle, and (ii) the total extant population of the species.

Population studies on the bushfly, a coprophagous muscid, in successively larger areas of its habitat in Australia were considered in relation to these concepts. The smallest unit of population studied, the group of larvae in a single faecal mass, most closely approximated its quantum-population. But then it was not until studies had been successively extended to include the bushfly population of the whole eastern third of Australia, that a potential evolutionary-unit population could be recognised. There are probably three such E-populations in Australia.

The changes in the type, and relative importance, of population adaptations which occurred as the proportion of the total habitat which was studied was increased, may have important implications for practical ecologists. When population studies of other species are considered in this conceptual frame of reference, they show marked differences in the relationships between their quantum-populations, evolutionary-unit-populations, and definitive-populations. Such differences could account for some of the difficulty in deriving a generally acceptable population theory.

TUNDRA AND TAIGA MOSQUITOES IN ALASKA

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Mosquitoes and associated biota were studied during the summers of 1970-1972 at two Alaskan localities. Sampling of the larval habitats of taiga mosquitoes revealed that potential aquatic predators of mosquitoes (mainly aeshnids, coenagrionids, corixids, gerrids, dytiscids, gyrinids, and chaoborids) were present throughout the warm season, but the mosquitoes had mostly emerged by the middle of June. The mosquito larval fauna consisted of 11 species of *Aedes*, 2 of *Culiseta*, *Culex territans*, and *Anopheles earlei*. *Aedes intrudens* was most common in collections from human bait. The tundra locality is located just south of the persistent fog shadow associated with the Arctic Coast. Among the environmental influences observed, wind had the most direct effect on mosquito flight activity. Relative humidity, temperature, time, and light intensity were correlated with flight activity. Eight species of mosquitoes, all black-legged *Aedes*, were present. A deet-treated net jacket prevented mosquitoes from biting for 45 hours.

THE BIOLOGY, ECOLOGY AND DISTRIBUTION OF THE GENUS *LACCOBIUS (LACCOBIUS)* (COLEOPTERA: HYDROPHILIDAE) OF THE NEW WORLD

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Both adult and larval *Laccobius* inhabit the shallow margins of streams and ponds. Larvae are predaceous and laboratory experiments revealed that chironomid larvae were a preferred, if not specific, prey. Experiments also showed that blood meals were necessary for the survival of the larvae. Adults fed primarily on detritus and small micro-organisms such as algae and diatoms.

Reproduction is bisexual. It is suggested that stridulation is the method by which males attract females or vice versa. Females construct silken egg-cases within which they lay from 2 to 11 eggs, the eggs hatching within 4 to 7 days. Larvae are strictly aquatic but move out of the water to pupate in moist soil near the water's edge. Life cycles are completed within 7 to 8 weeks. Unlike most hydrophilids, larvae are not cannibalistic and are gregarious.

Laccobius is distributed world-wide but is predominantly northern hemispheric. Only 12 species have been recorded from the southern hemisphere. Europe appears to be the centre from which world-wide distribution radiated. Fossil records are poor.

OBSERVATIONS ON THE BIONOMICS OF *ASPHONDYLIA BOERHAAVIAE* MOHN (DIPTERA: CECIDOMYIIDAE) IN JAMAICA W.I.

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Asphondylia boerhaaviae lays single eggs in the flower buds of several species of *Boerhavia* in Jamaica. Larval and pupal stages develop within a flower gall and the adult emerges after the pupa has wriggled half-way through the wall of the gall. Emergence is in the evening and copulation and oviposition occur within the 24 hour life span.

Midges were reared in captivity in large numbers and formed galls on potted plants in cages. The length of the life-cycle could thus easily be worked out.

Galls collected throughout Jamaica show that the midge is widespread and is attacked in the larval stage by 2 hymenopterous parasites. Life-tables were constructed for *Asphondylia* from various areas of Jamaica. Parasitization is generally high and it was possible to assess the operation of other mortality factors accurately because of the advantageous nature of the material.

INTERSPECIFIC COMPETITION AND COEXISTENCE OF ECOLOGICAL HOMOLOGUES IN THE COMPLEX OF *EURYGASTER INTEGRICEPS* EGG PARASITES

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During the period of oviposition by *Eurygaster integriceps* regular changes in the relative abundance of its polyvoltine egg-parasites are observed which result from competition for the reducing numbers of hosts. *Trissolcus grandis*, having a high development rate, displaces other *Trissolcus* species and particularly *T. volgensis*. Only *Telenomus chloropus* and *Ooencyrtus telenomicida* can withstand the competition, due to their ability to behave as secondary parasites and because of their advantages in larval competition by multiparasitism. In spite of this, a stable coexistence of different egg-parasites which use the same hosts and inhabit the same biotopes is observed. Experimental data show that this is caused by a sharply dissimilar relation to abiotic factors which favour different species in divers years and in various periods of the same season. The data obtained suggest a possibility of stable coexistence of ecological homologues. The competition between the egg-parasites of *E. integriceps* can differentially affect their joint efficiency in controlling the numbers of the pest.

THE DISTRIBUTION OF TWO LARVAL PHENOTYPES OF *CHIRONOMUS ZEALANDICUS* HUDSON (DIPTERA: NEMATOCERA) IN TWO EUTROPHIC LAKES IN NEW ZEALAND

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A twelve month sampling programme of the macrobenthos of two eutrophic lakes in the Rotorua region of the North Island, New Zealand, has revealed predominantly chironomid species.

According to the environmental conditions prevailing the larvae may be present as one or other or both of two phenotypes. These are: (1) thummi type larvae with four more or less equal-sized ventral tubules on the eighth abdominal segment; (2) salinarius type larvae with no ventral tubules.

Lakes Okaro and Ngapouri show different distributions of these two phenotypes. In Okaro the salinarius type is almost exclusively present whereas in Ngapouri both types are found. In the latter lake before thermal stratification salinarius is present at 2.5 metres and 5 m and thummi is present at 15 m and 20 m. At 10 m both forms are able to maintain themselves.

Their distribution is not directly influenced by depth because during thermal stratification the two types of larvae are found at shallower depths but in the same relative positions.

ECOLOGICAL ASPECTS OF EVOLUTION OF FAUNA OF CERAMBYCIDAE FROM SIBERIA

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The Cerambycidae from Siberia have populated broad-leaf and coniferous woods, open areas of meadows, steppes and semi-deserts. The fauna of Cerambycidae of broad-leaved forests is essentially more ancient. It flourished in tertiary times.

The fauna of coniferous forests is of later origin and is a derivative from that of broad-leaved forest formations. With the appearance of plantations of larch (*Larix* spp.), fir *(Abies sibireca)*, spruce *(Picea obovata)* and cedar *(Pinus sibirica)* groups of Cerambycidae adapted to them were formed.

It is assumed that the original fauna of Cerambycidae formed in dying trees. At a considerably later period groupings of species adapted to life on growing trees, on grassy plants and in the top-soil were formed. This process of adaptation (transition from dead wood, to physiologically weakened trees, to healthy trees) was the result of heavy selection pressures.

DYNAMICS AND PRODUCTION OF THE LARVAE *CHIRONOMUS BATHOPHILUS* KIEFF. IN THE LAKE DUSIA

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The larvae of *Chironomus bathophilus* Kieff. have great importance in the zoobenthos of the deep lake Dusia (the Lithuanian S.S.R.), which has a maximal depth of 32.4 metres and a mean depth of 14.7 metres.

They made up 21.8-28.8% of the biomass of zoobenthos (1.63 g/m^2) in July 1952, 93.5-96.1% (29.59 g/m^2) in November 1952; and 88.56% (11.23 g/m^2) in April 1966. Towards the end of the year the number of larvae were reduced to 44 per m^2 (33.33%) and the biomass to 0.09 g/m^2 (16.98%).

1967 was a bad year for *Chironomus bathophilus*. The number of larvae was very small, and many zoobenthical samples were without larvae.

In the second half of 1968 the number of larvae increased to 733 specimens/m^2 and their biomass to 13.62 g/m^2. Afterwards they decreased to 222/m^2 (4.17 g/m^2) (May 26, 1969).

A young generation of *Chironomus bathophilus* emerged in August 1969. The number of larvae then reached 8508/m^2. 1969 was a year of rapid growth of larval population.

The young generation of larvae was poor in 1970 (the average being 179/m^2). Towards the end of October a larva of *Ch. bathophilus* grew to 8.8 mg and they all reached the production of 1.57 g/m^2. The coefficient P/B of young larvae was 0.9.

In the lake Dusia the larvae that emerged in 1970, gave 31986 kg of biomass during 4.5 months. At the close of October 1970 the biomass of adult larvae reached 59357 kg. At the end of 1970 the biomass of *Ch. bathophilus* alone reached the total of 91343 kg.

Investigations into the biology of *Ch. bathophilus* have shown that these animals have a life cycle of 2 years (23 months).

A COMPARATIVE ECOLOGICAL AND ZOOGEOGRAPHICAL ANALYSIS OF THE ESTONIAN FAUNA OF STAPHYLINIDAE (COLEOPTERA)

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The 615 species of Staphylinidae account for 21% of the total number of species (2822) of the Estonian beetle fauna and are thus a predominant family. On the basis of a comparative ecological and zoogeographical analysis their different percentages in the local faunas of habitats are distinguished. They are least prominent in forests (18%) and most prominent in fens (42%). A comparison of the data with those on the corresponding Carabidae gives us criteria for estimating the relative importance and the specific value of Staphylinidae in their relations with the local existence conditions as well as in the genesis of the total fauna.

FAUNA OF PSYLLIDS (HOMOPTERA: PSYLLOIDEA) AND ITS DISTRIBUTION IN RELATION TO VERTICAL ZONATION

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Tadjikistan is an original and distinctive mountainous country. Heterogeneous relief and a varied ecological environment make favourable conditions for the occurrence of diverse fauna representatives including psyllids that are closely connected with fodder crops during all their life.

The psyllid fauna of Tadjikistan is characterised not only by the variety of species but also by the originality of its forms. Now one hundred and twenty species are found, and have been classified into four families and eighteen genera, and they include forty-three species that have not been described before.

Almost all the psyllid species are dendrophils with seventy-three species occurring on different trees and shrubbery, and forty-five species occurring on grassy vegetation.

Psyllids are phytophagous, and when they disperse to fodder crops they keep within particular vertical zonations. Species found on the plants of sandy deserts do not spread higher than 350-500 m altitude and thus occupy an area limited to valleys of the rivers in the south, south-east and south-west Tadjikistan. The same restrictive pattern can be seen in the dispersal of psyllids connected with broad-leaved forest vegetation of the lower and upper mountainous zone at heights of 1200-2800 m and even higher. Species that occur in this zone do not spread lower. Because of the climate and some other peculiarities, the fauna of psyllids in Tadjikistan in general is xerophilo-mesophileous.

SECTION NO. 7

BIOLOGICAL CONTROL AND INSECT PATHOLOGY

CONVENOR: E.McC. CALLAN

CURRENT STATUS OF THE BIOLOGICAL CONTROL OF *SALVINIA* IN AFRICA

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The neotropical aquatic fern *Salvinia auriculata* (Auct nec Aubl.) after its establishment on several water systems in Africa (as well as in Ceylon, Kerala and other areas outside Africa) has demonstrated an explosive growth pattern and become a serious aquatic weed. Following investigations on the natural enemies of *Salvinia* spp. in northern South America, three species *Cyrtobagous singularis* (Curculionidae), *Paulinia acuminata* (Acrididae) and *Samea multiplicalis* (Pyralidae) were recommended for field trials. Releases of one or more of these have been made on Lake Naivasha (Kenya), Lake Kariba and Zambezi River (Rhodesia and Zambia) and the Chobe River (Botswana). These areas were visited during October and November 1971 and the findings are reported.

THE POSSIBILITY OF CONTROLLED BIOLOGICAL CONTROL OF WEEDS

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Most attempts to control weeds by biological methods have involved plants whose noxiousness was indisputable. On occasions, a plant is at one and the same time a weed to one group of agriculturists and a useful plant to another. The classic example of this conflict of interest is the range weed which is also a honey plant.

A case is presented here that with a judicious selection of biological control agents it might be possible on the one hand to decrease the plant sufficiently to reduce its noxiousness but at the same time maintain enough plants to serve the useful purpose. The method consists of selecting: (a) those organisms which limit their attack to the agriculturally unused parts of the plant; (b) those organisms particularly effective in the habitat situation where control is required. Finally introducing the organisms in reverse order of potentiality until enough control is achieved.

EFFECTS OF FOOD AND LARVAL DENSITY ON THE FECUNDITY OF THE CINNABAR MOTH (*TYRIA JACOBAEAE* L.) AND THEIR RELEVANCE TO CONTROL OF THE FOODPLANT, RAGWORT (*SENECIO JACOBAEA* L.)

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Ragwort occurs in two phases, a vegetative and a generative phase. The vegetative phase either is a seedling or results from regeneration of a damaged plant. The influence of the two phases on the fecundity of the moth was tested. Differences were significant in favour of the generative phase.

Larval density in situations of excess of food is negatively correlated with adult fecundity.

However, both effects are small compared to that of food shortage. In the field up to 80% mortality through starvation was found. Rearings showed that the surviving caterpillars produced moths with a fecundity dependent of the quantity of food consumed before starvation. Food shortage results in periodic crashes (or extinction) of the population.

The lack of a regulatory mechanism brings about that *Tyria* is not able to exert a constant high pressure on its foodplant. Thanks to its regenerative power, strongly influenced however by weather factors, *Senecio* usually survives defoliation.

Biological control of *Senecio* by *Tyria* can be successful only under unfavourable (weather) conditions for regeneration and a constant high defoliation pressure. However, it will be very difficult to achieve the latter.

THE SELECTION OF EFFECTIVE AGENTS FOR BIOLOGICAL CONTROL OF WEEDS

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The preoccupation with safety in biological control of weeds has resulted in a high failure rate and cost. Seven methods for the selection of effective agents are discussed: (1) intuition; (2) availability - most abundant species are not effective agents; (3) parasitism of other people's successes - advocated but use limited by paucity of successes; (4) impact of agent in its native range - difficult to determine and not relevant unless parasites and ecological differences are discounted; (5) weed vulnerability to damage - often coincides with depletion of carbohydrate reserves; (6) weed-agent homeostasis - usually involves sacrifice in host specificity or use of non-abundant species; (7) successful attributes - determined from crop pests, which have similarities with successful agents. Each method has advantages but all are limited in scope. The use of the proposed multifactor scores incorporates many of their features and allows a comprehensive comparison of candidate agents for effectiveness.

EFFECTIVE DAMAGE TO WEED SPECIES BY NATURAL ENEMIES

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The nature of the term effective implies a preconceived aim which needs to be accurately defined and against which the damage produced by or likely to be produced by a candidate control organism may be judged. Crop loss evaluation techniques are seldom useful in such assessments and while acknowledging the problems of plasticity and vegetative regeneration, more emphasis should be placed on plant ecology and population dynamics, combined with the collection of appropriate quantitative data.

Knowledge of plant physiology, energy budgets and biomass relationships can be of considerable value but overall the ecology of the plant species attacked is crucial. Similarly, detailed comparisons may be made between the effects of individuals of different types of phytophages but consideration of the species as populations is more profitable in assessing their significance.

An examination of the range of natural enemies employed shows the varying significance of the type of damage produced and confirms the conclusion that for each situation a knowledge of the ecology of the weed species is of paramount importance.

HOST-PARASITE RELATIONSHIPS

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From the few well attested instances in which taxonomically related plants act as hosts to taxonomically related parasites, it is often assumed that host-parasite relationships are an overall guide to taxonomic relationships. Such a generalization is difficult to justify on theoretical grounds in that little is known of the biological basis of parasitism in most instances and that prior assumption of the premise has itself already influenced the taxonomy of both host and parasite groups.

To investigate the subject more objectively three types of study have been undertaken. Both grass-fungal disease and butterfly-host plant (monocotyledons) associations support the views that hosts and parasites each reflect the other's taxonomy, but only weakly so. Then statistical probabilities for observed host-parasite relationships have been estimated. Whilst it would appear that some relationships are non-random it is difficult to demonstrate that others are not so.

THE DETERMINATION OF HOST SPECIFICITY

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For biological control, insects are sought in which a firmly established behaviour pattern limits their host range to one or a small group of phylogenetically related plants. The nature of this pattern and if possible, its control should be borne in mind in the selection of test plants and testing techniques. This is best done by the research worker involved.

The selection of plants for determining the host range should be made according to the criteria of Wapshere (1971), i.e. primarily on the basis of phylogeny with safeguards for anomalous relationships and incomplete knowledge. This logical form of selection increases the reliability of the conclusions reached.

Techniques for testing plants are various and difficult to compare because of the variety of circumstances involved. Basically, no technique pertinent to an insect under study should be rejected as long as the selection behaviour remains intact, but the importance of field conditions for ensuring normal behaviour patterns is emphasized.

POPULATION DYNAMICS OF THE FRUIT-SUCKING MOTH *OTHREIS FULLONIA* (CLERCK) (LEPIDOPTERA: NOCTUIDAE) IN NEW CALEDONIA

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A three-year study was made in New Caledonia of population fluctuations of *Othreis fullonia* on the larval host plant (*Erythrina*) in an isolated valley, from which seasonal migration occurs. In a normal year damage is minimal, populations being limited by three species of hymenopterous egg-parasites, an egg-infecting fungus, several hemipterous and chrysopid predators, *Polistes olivaceus* (De Geer) (Vespidae), and *Winthemia caledoniae* Mesnil (Tachinidae), which parasitizes the larvae.

An abnormal year follows severe drought at the beginning of summer, when *Othreis* deserts the coastal plains and migrates to mountain valleys. Its population density is now low, but with the rains migration occurs to the coastal plains, where the moths lay eggs on the larval host plant. At this time oviposition does not coincide phenologically with the presence of egg-parasites, and a population explosion follows. Drought and the absence of egg-parasites, mainly *Ooencyrtus* sp., are the key factors in the population dynamics.

CHANGING STATUS OF THE PARASITES OF POTATO TUBER MOTH *PHTHORIMAEA OPERCULELLA* (LEPIDOPTERA: GELECHIIDAE) IN AUSTRALIA

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Three introduced parasites of *Phthorimaea operculella* (Zeller) are now established widely and a fourth in a limited area of Australia. *Apanteles subandinus* Blanchard, which occurs from Tasmania to Queensland, is the most effective species and the outstanding parasite in Victoria. It has been possible to monitor the extent of parasitism and status of the various parasites since they were first released, and, in many areas where *Copidosoma koehleri* Blanchard was the only parasite found in 1966, a substantial increase in parasitism has been recorded.

In the 1969-70 season there was an explosive increase in *Orgilus lepidus* Muesebeck, which has become the dominant species in some coastal areas of New South Wales, having largely displaced *A. subandinus*, presumably by interspecific competition Its changed status to a dominant position was correlated with an improvement in the sex ratio and is probably attributable to increased post-colonization adaptation.

EVALUATION OF PARASITES INTRODUCED AGAINST *SIREX NOCTILIO* (SIRICIDAE-HYM.) IN AUSTRALIA

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Since 1957 a total of 21 species of insect parasites have been introduced into Australia for the biological control of *Sirex noctilio*. These include species of *Ibalia*, *Rhyssa*, *Megarhyssa*, *Odontocolon* and *Schlettererius*, from Europe, North America, India and Japan. Four species are established and nine others should become established.

The strategy of the introductions was to obtain all parasites attacking siricids in conifers. The most effective species have come from Mediterranean type bioclimatic zones where *Pinus* spp. are components of the native fauna. However, evaluation studies have shown that in certain localities in Tasmania, because of retarded development of Sirex, *Ibalia leucospoides* is virtually excluded. *Ibalia drewseni* collected in more temperate climates is capable of replacing it in these localities, which would justify the strategy of broad scale collecting.

In a relatively dry area, the four species so far established have achieved parasitism of more than 60 per cent.

STATUS OF NATURAL ENEMIES OF WHITE WAX SCALE, *GASCARDIA DESTRUCTOR* (NEWST.) (HOMOPTERA: COCCOIDEA: COCCIDAE), IN EASTERN AUSTRALIA

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White wax scale (*Gascardia destructor*) (Newst.) is an important citrus pest in coastal New South Wales and Queensland. In citrus orchards, control by natural agencies is usually insufficient, but in some cases, where no insecticides are used, and the trees are large, with full leaf canopies, undisturbed plant ground cover and restricted exposure to wind, etc., native coccinellid beetles such as *Serangium bicolor* and *Orcus chalybeus* can keep the white wax population at low levels. Since 1968 CSIRO, Division of Entomology has liberated natural enemies from South Africa and from New Zealand. Two South African wasp species are established. *Anicetus communis* has made little impact on wax scale populations around Sydney. *Paraceraptrocerus nyasicus* has considerably reduced the incidence of wax scales on non-citrus plants, mainly oleanders, in the coastal area near the Queensland/New South Wales border.

THE VARYING INCIDENCE OF *EUXANTHELLUS PHILIPPIAE* SILVESTRI (HYMENOPTERA: APHELINIDAE) PARASITE OF *CEROPLASTES SINENSIS* DEL GUERCIO (HOMOPTERA: COCCIDAE) ON MANGROVE (*AVICENNIA RESINIFERA* FORST. F.) IN NEW ZEALAND

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The hard wax scale *Ceroplastes sinensis* which reached New Zealand about 1932 exploded in typical fashion, but subsequently fell to generally satisfactory levels. This has been due largely to parasitism by the aphelinid *Euxanthellus philippiae*, also a fortuitous arrival.

The coastal mangroves of the northern areas are a single plant community, and other scale species are rarely present, so the study virtually involves a single host plant, one scale insect, and a single parasite.

The incidence of *E. philippiae* in a persistently badly infested west coast area is compared with that in a typical east coast area where relatively good control is achieved. The influence of the proximity of the shoreline on the degree of parasitization has been studied. This together with temperatures allowing a second parasite generation appear to be significant factors.

TOWARDS THE BIOLOGICAL CONTROL OF OIL PALM HISPID IN GHANA

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The infestation area of *Coelaenomenodera elaeidis* Maul. is steadily expanding in the area between the Ivory Coast and the Camerouns. Chemical control has not been successful in most outbreaks, but a rich complex of parasites was found following investigations in Ghana. The parasites keep the hispid under control for a period of 5 to 6 years, after which the equilibrium breaks down and the pest populations develop anew to an outbreak proportion.

The unusual pattern of the population dynamics of the pest was recorded during a period which included two outbreaks. Simultaneously the population dynamics of the two egg and four larval parasites reared from the pest and some of them also from an alternative host (*Platypria coronata* Guerin) living on the cover crop (*Pueraria javanica*) were recorded.

Biological control measures will be introduced on the model of the successful control of the coconut hispid (*Promecotheca cumingii* Baly) in Fiji. Investigation, collection and introduction of hispid parasites will be carried out in cooperation with the Commonwealth Institute of Biological Control.

THE BIOLOGICAL CONTROL OF SUGAR CANE BORERS IN PERAK, WEST MALAYSIA

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The main sugar cane borers, namely, *Eucosma isogramma* Snellen, *Proceras sacchariphagus* Bojer and *Sesamia inferens* Walker, have been causing enormous losses in Perak, West Malaysia.

The most important egg-parasite of cane borers is an indigenous species *Trichogrammatoidea longiseta* to be described by H. Nagaraja. The writer used the eggs of the grain moth, *Pyralis farinalis* (L.), as hosts for mass-production of this species since May 1970. The egg-parasites were liberated in cane fields covering 1,500 acres, 3,000 individuals per acre being released, during 1970-71. The results showed that bored cane stalks in blocks where releases were made were 69% less than in the control and bored cane joints in release blocks were 75% less than in the control. The egg-parasite was very efficient in suppressing the population of cane borers.

FACTORS OF COMPETITION BETWEEN THREE TACHINID PARASITES OF *DIATRAEA SACCHARALIS* FAB. (LEP.: PYRALIDAE)

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Three tachinid parasites were successfully introduced into Guadeloupe, French West Indies, between 1938 and 1953 to control the sugar cane moth borer, *Diatraea saccharalis* Fab. The first of them, *Metagonistylum minense* Towns. is mostly confined to *Paspalum virgatum* stands, a spontaneous graminacae where it develops abundantly. *Lixophaga diatraeae* Towns. which was introduced in 1941 is by far the dominant species in sugar cane fields. The borders of these fields may be the site of an active competition between the two parasites. In some instances *M. minense* becomes dominant in the interior of the field itself.

Paratheresia claripalpis de Wulp has been liberated in 1953 and does not seem to have moved much away from the spots of release. Though its longer life cycle tends to place it at a disadvantage towards its two competitors this parasite has also been observed to be dominant in two localities.

STUDIES ON A SCELIONID EGG-PARASITE OF *ACANTHOMIA TOMENTOSICOLLIS* STÅL (HEMIPTERA: COREIDAE)

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Gryon gnidus Nixon (Hymenoptera: Scelionidae) is an egg-parasite of the pigeon pea coreid, *Acanthomia tomentosicollis* Stål in Nigeria. The life-cycle is completed in 8-14 days. The parasite is solitary and levels of parasitism in the field vary between 0% and 69%. The parasite is highly host-specific and eggs of other legume-infesting coreids including *Acanthomia horrida* Germ., *Anoplocnemis curvipes* F., *Mirperus torridus* Westw., and *Riptortus dentipes* F. are not attacked. Parasite population build up is related to host population dynamics but does not prevent the host populations from reaching economic injury levels.

THE IMPORTANCE OF WILD FLOWERS AND BUSH GROWTH AS A SOURCE OF FOOD FOR ADULT PARASITIC HYMENOPTERA

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The influence of abundance and accessibility of a food source on the effectiveness of parasitic Hymenoptera was investigated in three different areas, differing in the abundance of nectar and pollen producing flowers in the vegetation. The areas and their flora are described, and all entomophagous Hymenoptera found feeding on herbaceous flowers and grasses are listed. The relationship between the visiting insect and the host plant was determined by studies on the morphology of the insect's mouth parts, and on the anatomy of the host flowers, as well as quality assessment of nectar and pollen.

It was found that parasitic Hymenoptera do not possess prolonged mouth parts, and only visited and utilized as a food source those plants with extrafloral nectaries, or easily accessible nectaries and anthers. In areas where food was limiting, parasites were found to leave their biotope in search of food nearby, and the incidence of parasitism was highest in areas bordering the food sources. The availability of food had an important influence on reproductive capacity and longevity of the parasites.

THE USE OF FOOD SPRAYS TO AUGMENT THE NATURAL ENEMIES OF POTATO INSECTS

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Treatments of artificial diets based on Pred-Feed^R, a yeast product cultured on cottage cheese whey, and combined with honey and molasses were applied alone and in combination with systemic insecticides to potato plots in Idaho, U.S.A. The applications were made to determine their effects on the green peach aphid, *Myzus persicae*. Green lacewings, syrphid flies and predacious bugs were increased in treated plots. Honey treated plots showed the highest number of natural enemies. Food sprays may play a significant role in potato pest management.

INFLUENCE OF THE EVOLUTION OF CERTAIN MORPHOLOGICAL AND PHYSIOLOGICAL PROCESSES OF THE HOST ON THE SUCCESS OF PARASITISM

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The interdependence of an entomophagous parasite and its host are observable in the egg-larval parasite *Phanerotoma flavitestacea* Fischer attacking *Anagasta kuehniella* Zeller, in which the entomophagous larva penetrates the mid-region of the germinal band of the host. The success of parasitism depends on the age of the host egg in which the parasite lays. When eggs of a few hours old are attacked there is 100% parasitism. Survival of parasitic larvae is also largely dependent on physiological modifications of the host induced by environmental conditions. In *Ctenophorocera pavida* Meigen development proceeds under all conditions when *Galleria mellonella* L. is host; in noctuids like *Mamestra brassicae* L., *Amathes c-nigrum* L. or *Agrotis pronuba* L., for larvae reared at 20°C for 16-hour photoperiod, encapsulation occurs. This results in the formation of a cyst, which melanizes and causes the death of host and parasite. In larvae collected in autumn and destined to overwinter in the 4th or 5th instar, or 12 hours after being parasitized kept at 4°C and maintained thus for 2 or 3 months, no cyst formation occurs, even after the temperature returns to 20°C.

SIGNIFICANCE OF BASIC STUDIES IN BIOLOGICAL CONTROL

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The importance of basic research on the biology and ecology of biocontrol agents is discussed. Because of the complexity of synecology it may not be possible to predict the results of introduction with any certainty, but the possible unsuitability of a species for a particular area may be predicted if the autecology of the biocontrol agent has been studied. These studies should include intrinsic and extrinsic behaviour, effective rate of damage, climatic tolerances, host specificity, host selection, searching ability, adaptability, synchronisation, genetic factors, compatibility with other species, ability to disperse, etc. Information on these attributes can be obtained both from laboratory studies and from field data. These are discussed in some detail and the importance of such studies is emphasized.

THE PRINCIPLES OF BIOLOGICAL CONTROL IN GLASSHOUSES

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The stable, enclosed environment of a glasshouse and the short-term crops grown provide conditions for practical and predictable biological control. To ensure reliable results, each crop must be uniformly infested before (or at the same time as) the introduction of the natural enemy.

The strategy of control depends largely on the relative rates of population increase of both pest and natural enemy. If the latter multiplies the faster, rapid control is inevitable, as with *Tetranychus urticae* and *Phytoseiulus persimilis*. If increase rates are similar, the natural enemy may be favoured by adjusting the environment or by the use of partially resistant plant varieties (*Myzus persicae* control on chrysanthemums using *Aphidius matricariae*). If the pest multiplies faster, it is necessary either to introduce the natural enemy in such a high proportion that the pest increase is immediately curtailed or to assist biological control by the integrated use of chemicals.

DIFFERENCES IN THE LONGEVITIES OF MATED AND UNMATED *TELENOMUS REMUS* NIXON LIVING SOLITARILY AND IN GROUPS

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Telenomus remus is an egg parasite of *Spodoptera littoralis* (Lepidoptera: Noctuidae). In nature, the females mate shortly after emergence with males that wait for them at the emergence site, and are usually, their brothers. The females disperse after being mated.

In the laboratory, the longevities of the sexes, mated and unmated were examined. The median longevity of solitary mated females was only 2.5 days. It differed significantly from the longevity of females, that lived in groups of 4 or more individuals, both mated and unmated (18 and 13 days respectively). Solitary mated females that were separated only by a 300 mesh screen from the rest of the group lived 4.5 days, i.e. about as long as other solitary mated females. Males, whether solitary or in groups, lived much longer (7.5 and 9 days respectively) when unmated than when mated (1.5 and 2 days respectively).

The fact that the former lived only about $^{1}/_{5}$ as long as females in groups is presently inexplicable in light of the observation that in the field, females live as solitary individuals.

AVOIDANCE OF SUPERPARASITISM BY *PHAEOGENES CYNARAE* BRAGG (HYMENOPTERA: ICHNEUMONIDAE)

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Phaeogenes cynarae Bragg (1971), an internal, pupal parasitoid of *Platyptilia carduidactyla* (Riley), the artichoke plume moth (Pterophoridae), possesses an innate capacity to avoid the superparasitism of its host larvae. *P. cynarae* females exhibit an avoidance response within seconds of contacting a host larva previously parasitized by another *P. cynarae* female. The mechanism responsible for this response is a pheromone produced in the accessory (venom) gland of the female. The pheromone is injected through the ovipositor at the time of oviposition, and is systemic in nature, being capable of being detected by subsequent females within 30 seconds of its injection. That the pheromone is injected rather than wiped onto the host through the feet or ovipositor as has been supposed in other species, was demonstrated through experimentation, eliminating the possibility of these modes of application.

ANTS AS NATURAL CONTROL AGENTS FOR THE EASTERN SUBTERRANEAN TERMITE

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It is well known that foraging ants can prey upon exposed termites and also that some ant colonies can coexist with termite colonies with minimal barriers. The destruction of termite colonies by ants has not been well documented. Experimental evidence shows that *Lasius alienus* can destroy incipient and established colonies of *Reticulitermes flavipes*, and its predation may account for low termite populations where they might be expected to be abundant. The circumstances of attack are not yet clear, but the possible biological control of termites by augmenting these is indicated. This interaction of ant-termite colonial behavior may have practical significance when suburban housing developments are established in wooded areas of Connecticut.

PHENOLOGY OF REPRODUCTION IN A POPULATION OF INSECT PREDATORS

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A population of *Chrysopa carnea* Stephens (Neuroptera: Chrysopidae) was monitored as the animals proceeded into reproductive diapause, as they continued through diapause development, and subsequently as they underwent post-diapause morphogenesis leading to oviposition. We compared the diapause profiles produced by several diapause-inducing photoperiodic regimes.

COMPARATIVE MORPHOLOGY IN THE RECOGNITION OF CRYPTIC SPECIES

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Accurate systematics is the foundation on which all meaningful research in biology is based. The importance of sound systematics to practical biological control is illustrated with several projects of biological control of coccid pests. Correct identification of the pest species or their natural enemies, and recognition of cryptic species or infraspecific entities, have been of utmost importance to the success of such projects.

Sound morphology is the basis of reliable systematics. The scanning electron microscope is a valuable tool for comparative morphological research. The validity of morphological characters, and the extent of intraspecific variation, should be determined by a detailed biometrical study of large series of reared specimens. This approach is illustrated with results obtained in a recent revision of the species of *Aphytis*, important parasites of diaspine scale insects. Comparative morphology of developmental stages of parasitic Hymenoptera is recognized as an important approach to the study of cryptic species.

THE INVENTORY OF BENEFICIAL INSECTS

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Fully effective exploitation of parasitoids, predators, and weed feeding insects requires that information pertaining to identification, distribution, host range, biology and habitat requirements of all useful species be known. Despite parasite exploration and research conducted during the past 90 years, the number of known beneficial species is but a small part of the total available. Knowledge of the biological characteristics and ecological requirements of most known species is fragmentary and seldom sufficient for purpose of accurately predicting how effectively a species will perform as a control agent. The full potential of biological control can only be realized if a concerted and systematic worldwide effort is made to find, classify, and otherwise study all natural enemies of insect pests and weeds. Although a considerable total effort is now being expended in work that contributes to this end, the effort is fragmented and very often unproductive because of lack of coordination and continuity. Also there is serious duplication of effort. This is particularly true in the areas of insect identification and information retrieval. In both of these, a single internationally supported agency is needed.

PROBLEMS OF SYSTEMATICS IN APPLIED ENTOMOLOGY WITH SPECIAL REFERENCE TO BIOLOGICAL CONTROL

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The world-wide need for accurate, rapid identification of both host populations and entomophagous populations is critical for all scientists involved in biological control projects. Likewise, a world-wide Data Management System must be developed which will include biological, ecological and taxonomic data for plants and animals directly associated with biological control needs. Ways and means must be found by biological control workers to help establish priorities for systematists. This will necessitate fund-sharing programs. In cooperation with various institutions, museums and independent systematists biological control workers need to set priorities on groups of organisms in need of revision.

A plan will be outlined for solving some of the above problems, including the need for establishing an adequately funded International Applied Systematics Unit.

THE PLACE OF THE TAXONOMIST IN PROJECTS TO ACHIEVE BIOLOGICAL CONTROL

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Many of the most successful parasitic insects for use in projects for biological control have been discovered by searching in areas where the host insect is an uncommon or even rare insect. In all these instances the parasitic insects that were found proved to be unknown, requiring the services of taxonomists for their placement, description, and naming. Examples are *Anagyrus antoninae* Timberlake and *Neodusmetia sangwani* (Rao) against the Rhodes grass scale and *Tiphia vernalis* Rohwer and *popilliavora* Rohwer against the Japanese beetle.

Conversely, taxonomists may, as in the case of the European corn borer in Europe, compile a long list of parasites of a pest species in areas where it is common. These parasites, however, are obviously not effective in controlling the host insect there.

POST-COLONIZATION CHANGES IN INTRODUCED INSECT PARASITES

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Quantitative and qualitative differences in the physical environment, in the available food sources (hosts), and in the set of resident competitors present a challenge to the continued survival of a colonizing insect parasite in a new locality.

Selection will produce optimally adapted phenotypes that show differences in development and behaviour from the previous population mean. Morphological and biochemical criteria can be used to measure the degree and the rate of change in such populations.

The establishment of the aphid parasite *Aphidius smithi* in North America was characterized by gene frequency changes during the post-colonization period. The eventual establishment in eastern North America was accompanied by the appearance of a colour mutant *Orange* which reached a frequency of 7-10% in local populations. The period of rapid increase and dispersal between 1965 and 1967 was followed by the parasite's decline and almost complete disappearance from the eastern United States and Canada. Western populations remained largely monomorphic. They retained their competitive ability and continued invading new areas in western Canada.

Other changes that may affect the economic usefulness of introduced insect parasites include changes in host range, virulence, competitive ability, and synchronization with the target pest. Selected examples are given and discussed.

SYSTEMATIC RELATIONSHIP AND HOST RANGE

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The recent successful control of the stem borer, *Diatraea saccharalis* (Pyralidae), in Barbados by *Apanteles flavipes* (Braconidae), as Asian parasite of *Chilo* spp. (Pyralidae), draws attention to the control of a pest by parasites of related hosts. Studies of the parasites of these and other stem borers indicate that host selection may be determined as much by the ecology, behaviour and physical characteristics of the hosts as their systematic relationship. This contrasts with the situation encountered among scale insect parasites, but has been noted in other host/parasite complexes, e.g. leaf miners, although some of these may be found on careful study to represent groups of sibling species. Thus, in many instances parasites are as much affected by the ecology as by the taxonomy of potential hosts, so that in the selection of species for attempts at biological control a flexible approach is required.

STUDIES ON THE ECOLOGY OF A VIRUS DISEASE IN THE POPULATION OF *ORYCTES RHINOCEROS* L. (COLEOPTERA) IN WESTERN SAMOA

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The Indian rhinoceros beetle (*Oryctes rhinoceros* L.) is a pest of palm trees in many Pacific and Asian countries. The effect of a newly introduced virus disease (*Rhabdionvirus oryctes* Huger) on the population was studied in W. Samoa. The virus was found to be distributed evenly through the population. Although only about 3% of the larvae were infected with the disease the percentage of infected adults was found to be about 50%. Laboratory experiments showed that the fecundity and the life span is reduced in virus infected adults. Adults excrete virus material and can transmit it in this way to other adults and to larvae. Transmission from the female to its brood and from the larval through the pupal to the adult stage did not occur.

MICROBIAL CONTROL OF *SCHIZURA CONCINNA* (LEPIDOPTERA: NOTODONTIDAE) ON ORNAMENTAL TREES IN CALIFORNIA

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A programme using *Bacillus thuringiensis* formulations has successfully controlled larvae of *Schizura concinna* (Lepidoptera: Notodontidae), a defoliator of orchard and ornamental trees in California. Data from more than two season's work illustrates the use of field persistence and dose-response studies to provide a predictive estimate of larval mortality. The substitution of *B. thuringiensis* for the chemical insecticides formerly used, while in itself resulting in considerable reduction in control costs, is regarded as the first phase of an integrated control programme for this pest. A second phase is a modification of the landscape to further enhance the survival of two important parasitoids, *Hyposoter fugitivus* (Hymenoptera: Ichneumonidae) and *Apanteles* sp. (Hymenoptera: Braconidae).

THE EFFECTIVE USE OF NEMATODES AS BIOCONTROL AGENTS OF INSECT PESTS

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Recent advances in experimental parasitology have shown that entomophilic nematodes could be successful agents in a biological control programme if they are produced in large numbers, applied effectively and integrated with other control agents. The nematode *Mermis nigrescens* incorporates large quantities of leucine and glucose, but little glutamic acid and virtually no histidyl-leucine or haemolymph proteins from its host, *Schistocerca gregaria.* Such studies should facilitate the *in vitro* culture of mermithids in large numbers for control programmes. Uptake of nematode parasites depends on the biology of the host and on the method of application of the parasite. The oral intake of nematodes by foliage-feeding lepidopterous larvae and by particle-feeding simuliid larvae increases with temperature. Nematode desiccation is minimized by the addition of evaporation retardants at application. The efficacy of the nematode pathogen *Neoaplectona carpocapsae* in killing leather-jacket larvae, *Tipula paludosa,* is enhanced by applying it together with the β-exotoxin of *Bacillus thuringiensis* var. *thuringiensis.*

MICROBIAL CONTROL OF *ORYCTES RHINOCEROS* L. (COL.: DYNASTIDAE) IN MAURITIUS WITH THE VIRUS *RHABDIONVIRUS ORYCTES* HUGER

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Coconut rhinoceros beetles, first recorded in Mauritius in 1963, spread rapidly throughout the island, their development being favoured by the widespread occurrence of farmyard manure, resulting from a cow raising practice unique to Mauritius. Despite considerable efforts at control (larval destruction and introduction of natural enemies), the beetles killed hundreds of coconut trees and also attacked several species of other palm trees.

In 1970, the virus was introduced from Western Samoa. Infected material was multiplied in the laboratory and released in manure heaps. In 1971 a drastic reduction in larval numbers was recorded, and also a visible improvement in the condition of the trees. Infected larvae were collected in dead standing coconut trees, proving transmission by the adults. The virus normally kills the larvae but also has teratologic effects on the adults. This is the first successful natural control, but it is yet too soon to draw conclusions on its permanency.

EFFECT OF TEMPERATURE ON AMOEBA INFECTION OF THE MALPIGHIAN TUBULES OF THE HONEY BEE

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Healthy adult honey bees, *Apis mellifera* L., were individually inoculated by pipette feeding of a uniform volume of a suspension of the cysts of *Malpighamoeba mellificae* Prell, in a sucrose solution, and were kept in groups in cages at different temperatures. Bees kept at 21°C developed amoeba infections of their malpighian tubules in a greater percentage of bees, and to a greater severity in infected bees, than those kept at 32°C. Photomicrographs of the amoeba cysts, both in water mounts of the whole tubules, and in stained histological sections, are presented.

GRADIENTS OF DISPERSAL OF AN INSECT VIRUS DISEASE

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Spread of nuclear polyhedrosis virus disease in a population of Spruce sawfly, *Gilpinia hercyniae* Htg. (Hymenoptera: Diprionidae), in Wales in 1971 was at a similar rate to that observed in the first two generations following experimental initiation of a virus epizootic in this host in Canada (Bird and Burke, 1961). When plotted as logs, decrease in disease incidence (y) with distance (x) from the epicentre conformed to a straight line. This type of relationship is well known in epiphytotics; the gradient of disease can be measured by the regression (b) of y on x which generally as in our instances, has a negative value.

Canadian data indicate the gradient flattens and also becomes less smooth as the epizootic progresses. This again agrees with epiphytotics though the causes have not been investigated. Secondary spread outside the epicentre, increase in area of the disease source and the uneven density of host populations may be implicated.

The relevance of this botanical concept to practical microbiological control of insect pests will be considered.

USE OF MICROBIAL PATHOGENS TO SUPPRESS GYPSY MOTH, *PORTHETRIA DISPAR* (L.) (LEPIDOPTERA: LYMANTRIIDAE) POPULATIONS

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Field applications of the bacterium, *Bacillus thuringiensis*, and a nuclear polyhedrosis virus were evaluated against the gypsy moth, *Porthetria dispar*, a serious forest pest in the eastern United States. Various formulations of both microbial pathogens are considered in relationship to their effectiveness and the insect's behavior. An application rate of 8 billion international units of *B. thuringiensis* prevented defoliation of various *Quercus* species. Residue samples of the bacterial applications collected at different post-spray intervals and bioassayed against second stage larvae indicated residual activity up to 4 weeks. Timing of application using the amount of leaf expansion and larval stage as an index was important in obtaining effectiveness. Laboratory bioassay methods are given for both *B. thuringiensis* and *P. dispar* nuclear polyhedrosis virus. Using a bioassay technique where the virus was incorporated into an artificial medium the LC_{50} against 2nd stage larvae was found to be 4.11×10^3 polyhedra.

POTENTIALITIES OF RADIATIONS FOR INHIBITING THE DISEASES OF INSECTS REARED ON A MASS SCALE

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Control of antibiotic-resistant insect pathogens is a serious problem and radiations have potentialities for suppressing insect diseases. Development of *Borrelinavirus bombycis* was inhibited in 100, 1,000 and 10,000 r X-irradiated *Bombyx mori* larvae. *Galleria mellonella* larvae, exposed to 1,000 and 10,000 r of X-radiation and infected with VND 24 hours later, survived to adults. *Heliothis* virus developed a little in 10, 15 and 20 Kr irradiated *G. mellonella* larvae.

Hemerocampa leucostigma irradiated with ^{137}Cesium showed resistance to *Bacillus thuringiensis*. Characteristic pattern of *B. thuringiensis* attack was absent on midgut epithelial cells of 20, 50 and 70 Kr γ-irradiated *G. mellonella* larvae. Infrared-irradiated *G. mellonella* larvae showed inhibited development of TIV and survived to adults. Nuclear or cytoplasmic polyhedrosis was not induced in ultraviolet-irradiated *B. mori*. Infrared, X and γ-irradiated larvae developed thick cell walls and vacuoles in cytoplasm and nucleoplasm, and problem of permeability of irradiated cells to chemical components of pathogens needs investigation.

SECTION NO. 8

NON-INSECTICIDAL CONTROL

CONVENOR: R.J. BARTELL

MAJOR CONSTITUENTS OF THE TRAIL PHEROMONE OF THE CALIFORNIAN DAMP WOOD TERMITE *ZOOTERMOPSIS NEVADENSIS* (HAGEN)

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Organic solvent extracts from several castes of *Zootermopsis nevadensis* termites form artificial trails on filter paper. By modifying an available method, a quantitative behavioral bioassay was developed to determine the biological activity of fractions throughout a purification procedure. This involved several steps of enrichment such as steam distillation, liquid-liquid extraction, high vacuum distillation and gas chromatography. Chemical identification of several active components present in two major fractions was accomplished by combined capillary gas chromatography-mass spectrometry. Free fatty acids with 5 up to 8 carbon atoms form highly active artificial trails when applied in moderate concentration, but act as repellents in high concentrations. The trail stabilizing function of some biologically inactive long-chain hydrocarbons, also identified in the fractions, is discussed.

DIHYDROPYRROLIZINE PHEROMONES

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Since 1-methyl-7-oxo-6,7-dihydropyrrolizine was first isolated and identified as an important male danaid butterfly pheromone, dihydropyrrolizines have been isolated from the 'hair-pencils' of many danaid species and from male moths of the family Arctiidae.

The danaid species in the New Hebrides have been examined and their hair-pencil dihydropyrrolizines identified. Observations of a strong wind-borne attraction of male danaids and a feeding response provoked by the hair-pencil extracts of other males suggest that an unusual chemical communication system exists between male danaids. Attraction of male danaids, feeding and homosexuality have also been elicited by plants containing pyrrolizidine alkaloids. Pyrrolizidine alkaloids are potential precursors of dihydropyrrolizine pheromones. Male arctiid moths almost certainly obtain their dihydropyrrolizines (or precursors) from larval food plants and there is evidence that male danaid butterflies also obtain their pheromones from plant sources but in this case as adults rather than larvae.

PHEROMONES INVOLVED IN DEFENSIVE BEHAVIOUR IN AN AUSTRALIAN SPECIES OF *CAMPONOTUS* (FORMICIDAE)

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Throughout the Formicidae there is an evolutionary trend away from aggressive behaviour displayed against other species, as in primitive, sting-bearing Myrmeciinae and Ponerinae, towards purely defensive reactions, as in highly advanced, spraying ants such as Dolichoderinae and Formicinae.

Defensive behaviour in *Camponotus* (Formicinae) is controlled by pheromones differing in glandular origin from the pheromones controlling aggressive behaviour in *Myrmecia* (Myrmeciinae). Reasons for the change are examined against a background of the position in other Formicidae and related Hymenoptera.

It is suggested that, in general, "alarm", which is a component of both aggressive and defensive behaviour, assumes greater importance the more highly evolved the behaviour pattern becomes. This view is supported by data from the case of *Camponotus*.

Particular attention is given to the problem of whether formic acid, produced in the venom gland of the present Australian *Camponotus* as in other Formicinae, possesses some pheromonal activity in addition to its directly defensive function against other species.

FIVE YEARS OF PHENOLOGICAL OBSERVATIONS OF THE SUMMERFRUIT TORTRICID, *ADOXOPHYES ORANA* (LEPIDOPTERA: TORTRICIDAE) WITH SEX TRAPS

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Adoxophyes orana is considered to be the key-pest in Dutch pome fruit orchards. In commercial orchards it is general practice to control the moth with broad spectrum insecticides: 1-2 sprays against the first generation in June, and 2-4 sprays against the second generation in August/September. Sprays are most effective while newly emerged larvae are migrating to young shoots. It is possible to determine the optimum spraying dates by monitoring adult numbers. Light traps have been used for this purpose for the last 15 years with variable results. Since 1968 sex traps have also been utilised. Traps were initially provided with live *A. orana* females or crude extracts as a pheromone source but synthetic pheromone has been available since 1971.

Sex traps are useful because of their relative specificity and ease of maintenance. Another advantage is the highly sensitive detection of low moth populations. This does not, however, apply when populations are large. Problems concerning the relationship between population density in the field and numbers of moths caught in sex traps are discussed.

LABORATORY AND FIELD STUDIES OF THE RESPONSE OF FEMALES TO THE MALE SEX PHEROMONE OF THE QUEENSLAND FRUIT FLY, *DACUS TRYONI*

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A laboratory bioassay for the male sex pheromone was developed and a response curve of percentage female response against male equivalents obtained. The probing of the ovipositor of the female towards the source of the pheromone was used as the key response in the bioassay. The factors effecting the response of females were then determined using a standard concentration of 4 male equivalents. The degree of maturation of the ovaries, mated state, time of day and the dusk light intensity all had a marked effect upon the female response.

The response of females to Steiner type traps baited with different amounts of pheromone was studied in large field cages over fruit trees.

THE DEVELOPMENT OF ATTRACTANT TRAPPING SYSTEMS FOR *ORYCTES RHINOCEROS* (COLEOPTERA: SCARABAEIDAE)

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The volume screening approach to the search for insect attractants was followed, and two chemicals, ethyl dihydrochrysanthemumate and ethyl chrysanthemumate were found to attract the coconut rhinoceros beetle, *Oryctes rhinoceros* (L.). Since this beetle occurs at a low density, several problems were encountered in field testing of these attractants. Trapping systems were developed for use in control programmes and these are also being used in survey and ecological work. The effectiveness of the attractant, ethyl chrysanthemumate for controlling outbreaks of the beetle is discussed.

PHEROMONES OF INSECTS IN NEW ZEALAND: PHENOL FOR THE CONTROL OF GRASS GRUB *COSTELYTRA ZEALANDICA* (WHITE) (COLEOPTERA: SCARABAEIDAE)

R.F. Henzell

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The variation within the female grass grub beetle of the sex pheromone, identified as phenol, is discussed in relation to mating behaviour in the field. The electroantennogram has been used to compare the activity of phenol with closely related phenolics. These compounds had no masking effect on the antennal response. A comparison in activity between phenol and a crude female extract, indicated phenol as the sole pheromone.

Field studies on the optimum rate of release for attraction, the distance of attraction and the concentration of phenol in air to cause confused flight behaviour are considered.

REPELLENT SOIL MULCHES FOR PROTECTING CROPS FROM PHYTOPHAGOUS INSECTS AND VIRUS DISEASE INFECTION

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Field studies with soil mulches, conducted from 1963 to 1971, showed that reflective aluminum was highly repellent to alate aphids entering the field and reduced infection of several aphid-borne viruses including CMV and WMV-1. Bush squash, peppers, Chinese cabbage and gladioli were successfully grown in areas where virtually complete losses from virus infection occurred as insecticides had failed to control the vectors.

Roses and gladioli were protected from attack by flower thrips and gladiolus thrips, respectively. Damage by the potato leafhopper (*Empoasca fabae*) was reduced or prevented on dahlia and seedling trees. Adult Mexican bean beetles were repelled from mulched snap beans. The degree of protection ranged from 80% to 95% in the experiments with vector aphids, thrips, leafhoppers, and bean beetles.

Aluminum foil on wet proof paper and equipment for laying it in the field are commercially available. The high cost of mulch limits its use to high value crops. However, increasing acreages of mulched cucurbits, peppers, and chinese cabbage are being profitably grown, especially in New Jersey.

COMBINATION OF BEHAVIOURAL AND HORMONAL PRINCIPLES FOR INSECT CONTROL

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Study of non-insecticidal chemicals for the control of mosquitoes, houseflies and certain phytophagous insects has been undertaken. The chemicals tested may be arranged into three categories according to their effects on the insects: (i) Juvenile hormone mimics which inhibit development of the insects but are behaviourally inert or repellent. As adequate exposure of the insects to such chemicals cannot be ensured, they are ineffective for control. (ii) Chemicals attracting or inducing feeding or oviposition but ineffective in interfering with their development. These chemicals can be used only as baits mixed with other devices for control. (iii) A few which combine both the above properties. These have a greater scope for the control of the insects.

PREDICTING PLANT SUSCEPTIBILITY OR RESISTANCE TO PESTS FROM PLANT CHARACTERISTICS

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When mechanisms of plant resistance are understood, it becomes possible to 'risk-rate' plants to pest attack by measurements made on the plants.

This is valuable in shortening plant breeding programmes and in screening new crop management programmes for host plant induced effects on pests.

Examples of such 'risk-rating' possibilities can be cited and include the possibility of predicting plant susceptibility to certain aphids based on chemical analysis for only a few leaf amino acids.

The main limitations of the idea are a restriction of screening to certain resistance mechanisms and the variability in efficiency of some of these mechanisms under different environmental conditions. Paradoxically, the latter limitation gives the approach particular practical value.

EXPERIMENTS TO ELUCIDATE THE MODE OF ACTION OF AN ORGANOTIN ANTIFEEDANT IN LARVAE OF THE EGYPTIAN COTTON LEAFWORM, *SPODOPTERA LITTORALIS*

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Organotin insect antifeedants have been studied quite extensively in recent years.

Attempts were made to clarify the mode of action of the antifeedant, fentin acetate, on larvae of *Spodoptera littoralis*. Results of differential feeding experiments, maxillectomy, extirpation of antennae, microfeeding larvae directly into the midgut and injecting the compound into the haemocoel indicated that the site of action was probably in the gut.

Protease and amylase activity (determined under optimum conditions) in larvae which had been fed plant material treated with fentin acetate, was strongly inhibited. When larvae that had been prestarved for one day were offered such food, both the proteolytic and the amylolytic activity dropped to practically zero.

INSECT ANTIFEEDANTS IN PLANTS

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Insect antifeedants contained in plant leaves were widely surveyed by monitoring with "leaf disks". *Spodoptera littoralis* Boisd. was the test insect and leaves of *Ipomoea Batatus Lamarck var. ldulis* Makino the insect baits.

Leaves of *Clerodendron trichotomum* Thunberg, *Orixa japonica* Thunberg and *Boenninghausenia albiflora* Maissner *var. japonica* S.Suzuki contained very potent insect antifeedants the chemical structures of which were elucidated by chemical and X-ray analysis.

These chemical structures have suggested the parent structure of insect antifeedants, and several related compounds were assessed for antifeedant properties.

INSECT MOULTING HORMONE AND TOXIC SUBSTANCES IN NEW ZEALAND PLANTS

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Testing of a range of New Zealand plants by incorporating dry powdered leaf samples in house fly larval diet has shown that several species possess toxic or feeding inhibitory properties.

In some instances this is associated with high levels of insect moulting hormone substances but in other cases more directly toxic materials appear to be involved. Some of the chemical compounds concerned have been isolated and identified. Their activity against other insect species is being examined.

FRUIT-PIERCING MOTHS: ECOLOGY AND CONTROL

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Noctuid moths of the genera *Serrodes, Calpe, Pericyma, Plusiodonta* and *Orthreis* cause extensive damage to deciduous fruit in Southern Africa. *Serrodes partita,* a migratory species, is the most important on peaches in the southern and western Cape Province. Outbreak populations, which occur every five to seven years, appear to be regulated by rainfall causing the host plant to flourish in the breeding area at a critical time.

Moths enter orchards shortly after dark to attack ripe fruit. Invasion is directional with the leeward margins being the most heavily attacked.

Baits so far developed have not been attractive and insecticides are not effective nor are they permitted on ripe fruit. Repellents seem to hold the only hope for control. Mercury vapour, yellow incandescent and kerosene pressure lamps placed along the orchard perimeter reduced moth numbers by as much as 90%.

VARIATION IN BACTERIOSTATIC ACTIVITY OF DIFFERENT PLANT SPECIES WITH THE AGE OF FOLIAGE

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Juices of young and fully-grown leaves of 4 plant species were tested for their inhibiting effect on the growth of *Bacillus thuringiensis thuringiensis*, *B. th. dendrolimus* and *B. th. sotto*. Results indicate a marked increase in the inhibiting effect of the foliage on the 3 bacterial varieties with growth of the leaves. This difference was more marked in the case of *Morus alba* and *Ficus sycamorus*. On the other hand growth had practically no effect on the inhibiting activity of *Allium kurrat*.

OPTIMAL CONTROL OF INSECT REARING AND RADIATION STERILIZATION

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Evaluation of parameters in insect rearing means assessment of their influence in several areas simultaneously. The breeding temperature of codling moth, *Laspeyresia pomonella* L., for example, affects the development rate, mortality, fecundity (which is important in mass rearing), longevity, and mating activity (which affects the rate and frequency of sterile male releases). Temperatures giving the highest development rate also cause physiological defects.

Similar problems occur with radiation sterilization of insects. Doses producing complete sterility, especially in Lepidoptera, have a negative influence on mating activity. Reduction in the radiation dose will decrease side effects but also reduces the sterilizing effect.

The problem of estimation of optimal parameters can be solved as an optimization problem, using mathematical methods of the theory of optimal control and modern computer technique.

This has proved successful as evidenced by the practice of optimal control of codling moth rearing, based on the search for an optimal breeding temperature.

STERILIZATION OF ADULT RICE STEM BORER, *(CHILO SUPPRESSALIS)*

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In the sterilization of adult by irradiation, the important function is to obtain a genetic dominant lethal mutation, and the dominant lethal mutation is calculated from the number of eggs fertilized by sperm.

The female adult of rice stem borer has a sex attractant and is approached by the male. Therefore, when the male adult shows no reaction to the sex attractant of the female, it is because his spermatophore and spermatozoa are as yet unformed.

In order to control the sterile situation so that we could identify newly formed chromosomes with mutant, we treated with radiation the germ cells of rice stem borer in the period before chromatid duplication. This enabled us to sequester the mutant within the original germ cells and to determine mortality of F_1 larvae.

INDUCTION OF DIAPAUSE IN *HELIOTHIS* SPP. AND THE EFFECT OF GAMMA RADIATION ON DIAPAUSING PUPAE (NOCTUIDAE: LEP.)

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Induction of diapause was studied for possible application in integrated control techniques. *Heliothis zea* and *H. virescens* were reared on artificial diet and diapause was induced in bioclimatic chambers. Diapausing pupae were treated within 48 hours or stored at 4-5°C in the dark for a period before treatment with radiation from a Co60 source.

Adults were examined for longevity, number of eggs, fertility and number of spermatophores transferred to females. Results indicated that diapausing pupae were affected by storage. Radiation doses greater than 5 Krad were lethal or caused damage. Sub-sterilizing doses produced almost normal individuals. However, irradiation of pupae by 3.5 and 2.5 Krad resulted in reduced longevity and egg production. The progeny from matings involving irradiated males showed more abnormalities than those from irradiated females.

CONTRIBUTION TO THE MASS REARING OF THE OLIVE FRUIT FLY (*DACUS OLEAE* GMEL.)

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This is a progress report on advances in egg collection techniques. Egg masses of rearing size are obtained through the use of a new type of large parallelepipedic cage which has the two larger sides covered with Parafilm M, which is used for the first time for this purpose.

Eggs oviposited through the film are flushed down twice a day by a jet of water and collected in a funnel with nylon, a procedure which takes less time and work than the former one.

Further operations are analysed and the sequence of operations with this type of cage is considered with respect to mass production.

MATING ACTIVITY AND COMPETIVENESS OF ARTIFICIALLY REARED (MALES NORMAL OR γ-RAY STERILIZED) AND WILD *DACUS OLEAE* (GMEL.)

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Wild flies, reared in the laboratory on olive fruits (W), and flies reared on artificial diets (AD) were mixed in various type and sex ratios as soon as they were sexually mature. In some experiments the AD male pupae were sterilized at 8000 rads of Co^{60} γ-radiation one day before adult emergence.

Longevity was practically the same in normal W and AD flies of both sexes, but was slightly decreased in the irradiated AD males. The intermating period for females (with either W or AD males) was much shorter in W females than in AD females. The phenomenon was more striking during the first 35 days when the intermating period was 6-10 and 13-18 days respectively. When normal W and AD males competed for W females, they were equally successful, but irradiated AD males were fully competitive only during the first week. Subsequently they were less active than the W males by a factor of 3 to 4. Egg hatch was markedly reduced only during the first 4 weeks.

GAMMA STERILIZATION AND SEXUAL COMPETITIVENESS IN THE OLIVE FRUIT FLY (*DACUS OLEAE* GMELIN)

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Dacus oleae was irradiated with gamma rays at all stages of the life cycle. Radiosensitivity, mating competitiveness of males and sexual behaviour were examined for the suitability of the sterile male technique in the control of this species.

Pupae irradiated with 8 krad 3 days before emergence produced vigorous males with sterile spermatozoa and females (more radio-sensitive) which did not oviposit. Longevity was not affected.

The number of matings and those which involved sperm transfer was reduced in sterile males.

Most females (normal or irradiated) would only mate once but in the few cases of multiple mating fecundity was determined by the fertility of the last male to mate. The optimum ratio of sterile to normal males in field and laboratory tests was 8:1.

THE HEALTH OF RADIATION-STERILIZED *DACUS CUCUMIS* (DIPTERA: TEPHRETIDAE)

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Nutrition and respiration of flies irradiated with 10 krad were not demonstrably different from those of normal flies. However, initial body weights of irradiated flies were lower, and irradiated females accumulated more fat body than normal flies.

Secretion of gonadotrophic hormones by females was not reduced by 10 krad, because undeveloped ovaries transplanted from normal to sterilized flies developed eggs. The median neurosecretory cells of normal and irradiated females were histologically similar. However, the corpus allatum in irradiated flies was hypertrophied; this may represent a stress reaction to irradiation.

Locomotor and mating activity were not significantly affected by 10 krad but at higher doses, locomotor activity and male mating activity decreased, while female receptivity increased. The storage of male sex pheromone was not affected by irradiation.

Dose-mortality curves indicated a reduction in lifespan with increased dose, except at 5 krad where female lifespan was 126% of controls.

TEN YEARS OF STERILE MEXICAN FRUIT FLY RELEASES IN MEXICO

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Previous to 1964 costly applications of malathion were made periodically in northern Baja, California for eradication of the Mexican fruit fly, *Anastrepha ludens* (Wied.), emerging from contraband fruit arriving at the Mexican-Californian international border. In 1962-63 releases of tepa-sterilized flies in a 10 acre mango grove in central Mexico proved effective in suppressing infestations. This sterile fly release procedure was adopted for use in 1964 for area-wide suppression by the Plant Protection Division, USDA, in northwest Mexico. Release of tepa-sterilized sexually mature adults in 1964-65 and since then irradiated flies have affected complete suppression. This paper reviews these programs and summarizes records of fly dispersal in Mexico and California.

JUVENILE HORMONE ANALOGUES AS CHEMOSTERILANTS

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Analogues of the juvenile hormone are effective chemosterilants. Their chemosterilizing effects vary according to species, compound and time of application.
1. Applications to last instar larva and pupa may prevent full development of reproductive organs (absence of outlets, malformation of accessory glands).
2. Delayed applications to last larval instar, pupa or young adult affect ovaries and oogenesis. Development of prefollicular cells is inhibited, differentiation in germarium is deranged, descending oocytes are not enveloped, older ones degenerate, follicular epithelium proliferates. 3. Testes and spermatogenesis are similarly affected. 4. The number of eggs laid decreases (sometimes, on the contrary, increases), many are abnormal, most of them do not develop. 5. After application to reproducing adults normal eggs are laid, mostly dying during embryogenesis.
6. Embryonic development is inhibited at various stages. Diminutive and malformed embryos occur frequently. Vapours of some analogues are also effective. The analogues are compared with classical chemosterilants.

STERILIZING EFFECT OF HIGH TEMPERATURES ON *DROSOPHILA MELANOGASTER* (DIPTERA)

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Strains Oregon RC and Bar of *Drosophila melanogaster* differ in sensitivity to high temperatures.

1. Generation F_0 reared at 25°C and transferred to 30°C or 32°C immediately after adult emergence:
(a) Bar is always more thermosensitive than Oregon.
(b) At 30°C, F_1 Bar males are totally sterile but some F_1 Oregon males give rise to sterile F_2 progeny. Although all males can recover when transferred to 25°C after emergence, the F_2 Oregon are of very low fertility.
c) At 32°C, neither strain produces an F_1.

2. Generation F_0 transferred to 30°C or 32°C at different times during the pupal stage:
(a) F_0 imagos maintained at 30°C are either like 1(b), or produce no F_2, or are totally sterile.
(b) F_0 imagos transferred from 32°C or 30°C to 25°C may be highly fertile, or (after a progressively longer delay) decreasingly fertile, or irreversibly sterile.

OUR EXPERIENCE ON HOUSEFLY CONTROL BY THE STERILITY METHOD (1960-1971)

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The field and laboratory work carried out in Italy for the control of *Musca domestica* L. by sterilization is briefly reviewed. A field trial in progress in a rural area of central Italy is described. It appears that satisfactory control may be obtained by the release of sterile males provided that: 1. The initial field population is reduced by chemical or seasonal factors. 2. The number of released males is 5-6 times that of the male field population. 3. Releases are performed at least twice a week during the warm season and once a week during the cooler months, in order to maintain the size of the sterile population. 4. Sterile males should be evenly distributed over the area to avoid concentration in a few dwellings.

Released males do not need to be 100% sterile, a sterility of 90-98% being sufficient for satisfactory results. Control rather than eradication should be the aim as reintroduction of flies will soon occur.

FIELD AND LABORATORY EXPERIMENTS WITH CERTAIN CHEMOSTERILANTS FOR THE CONTROL OF THE ORIENTAL HOUSEFLY *MUSCA DOMESTICA VICINA* MACQ. (DIPTERA: MUSCIDAE)

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Studies on the chemosterilization of *Musca domestica vicina* have been undertaken to test the feasibility of this technique for its control. An almost completely isolated oasis in the western desert was chosen for field experiments and release of sterile males.

The relative potencies of the chemosterilants tepa, metepa, apholate, thiotepa and hempa, either incorporated in the adult fly food or in the larval medium or applied as residues on glass surfaces, were studied. Apholate and tepa when fed to adults proved very effective against both sexes. Mating competitiveness tests using normal wild females showed that tepa-sterilized laboratory males were at least as competitive as wild untreated males. The relative effectiveness and attractiveness of dry and liquid baits treated with chemosterilants were also examined. Release of tepa-sterilized males and the results obtained are described and discussed together with suggestions on an integrated approach.

N-N'-TETRAMETHYLENEBIS (1-AZIRIDINECARBOXAMIDE) (=ENT50838,TMAC) AS A CHEMOSTERILANT FOR THE HOUSEFLY: FIELD AND LABORATORY BEHAVIOUR OF TREATED INSECTS

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Male *Musca domestica* L. sterilized with TMAC compete effectively with normal males in the search for and insemination of virgin females. Laboratory data show that the mating activity of treated males slightly exceeds that of the untreated ones.

Field releases of chemosterilized, marked males were performed throughout the year. Sexual behaviour, movements and influence on the natural numerical increase of the wild population were assessed using recapture, population estimates and fertility of wild females. The results are shown and discussed.

PROPOSALS FOR THE APPLICATION OF GENETICAL CONTROL TECHNIQUES IN THE ERADICATION OF HARMFUL APHID SPECIES (HOMOPTERA: APHIDINA)

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The sterile insect release technique could be used for the eradication of holocyclic-heterogenetic aphid species provided that they meet the following conditions: 1. Hibernation be performed only on the primary host by the diapause egg produced by the bisexual generation, or by the first larval stage of the fundatrix. 2. Males to be sterilised must be winged, and thus, through their dispersal, have a wide range of influence. Some restrictions to the application of the technique are considered. Compared with other insects, these aphid species offer one great advantage for the application of this technique: The bisexual generation develops only once a year and always in a stage of general population decrease. Observing the two requirements above, investigations are in progress with the mealy apple aphid (*Dysaphis plantaginea*) and the hop-damson aphid (*Phorodon humuli*).

SECTION NO. 9

POPULATION MANAGEMENT AND INTEGRATED CONTROL

CONVENOR: P.W. GEIER

ON SOME GENERAL PRINCIPLES IN THE CONTROL OF PARASITIC ARTHROPODS, WITH PARTICULAR REFERENCE TO WARBLEFLIES

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Biological control does not necessarily imply the use of inimical organisms, but may be practised by exploiting more fully such regulatory systems as occur naturally.

The natural system regulating warblefly numbers involves (a) density-dependent factors determined by parasite-host interactions, which define the general level of parasite abundance according to the properties of the species; and (b) climatic influences governing distribution, periodic fluctuations in population numbers, and the local phenology of the species.

For optimal effect, control measures against warbleflies should be synchronized with the action of natural limiting agents, in order to avoid compensatory reactions in the target populations. The value of this approach has been confirmed during the last seven years in large areas of the U.S.S.R.

Understanding the ecology of target populations is basic to the development of biologically-based methods for the control of medical and veterinary pests.

THE MANAGEMENT OF POPULATIONS OF THE CATTLE TICK *BOOPHILUS MICROPLUS* IN AUSTRALIA

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The cattle tick, a major pest of cattle in northern Australia, produces debilitating infestations and transmits *Babesia* blood parasites. The failure of acaricides to provide a reliable means of suppressing tick numbers, and the problems associated with eradication and with vaccination against *Babesia* have led to the consideration of an approach aimed at managing tick populations through the use of tick-resistant cattle. A successful approach will require the maintenance of tick numbers at levels low enough to be tolerable, but sufficiently high to ensure transmission of *Babesia* at a level which will maintain the immunity of the cattle. There is a wide range of favourability of habitats for *Boophilus microplus*, just as there is a wide spectrum of host resistance to ticks. The aim in developing a management approach is to select the appropriate degree of host resistance for any given locality.

INTEGRATED CONTROL OF BLOOD-SUCKING DIPTERA IN SEASHORE AREAS

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Control of salt marsh mosquitoes began 60 years ago by managing water levels and providing access for minnows to breeding areas. Drainage, tide gates, and similar water management techniques were developed. Under adverse climatic conditions large mosquito populations may require use of insecticides against aquatic stages or adults. Minimum dosages have resulted in little damage to predators and in little evidence of resistance to insecticides. High levels of resistance have been encountered in other states where insecticides have been used in larger quantities.

Mosquito control agencies have given little attention to other biting flies. The populations of some species of *Culicoides*, *Tabanus*, and *Chrysops* may have been increased through mosquito control. Scientific data is essential to develop water management and other techniques for control of immature stages of other biting flies. Then an integrated program can be developed for control of the whole complex even including *Stomoxys calcitrans*.

THE EFFECT OF THE ALTERATION OF ENVIRONMENT ON THE POPULATIONS OF *AMBLYOMMA HEBRAEUM* KOCH

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Field observations on the incidence of *A. hebraeum* on domestic stock in different areas of the Eastern Cape Province of South Africa suggest that vegetation cover has a direct influence on the abundance of this species of tick.

Larvae have been shown in laboratory experiments to prefer to settle at specific heights on vegetation and the possible effect of this response in moderating populations is discussed.

The effect of artificially altering the height of pasture appears to be a possible means of controlling *A. hebraeum* infestations, and field records are presented which suggest that the height of vegetation has a greater influence on *A. hebraeum* populations than has the plant variety within the pasture.

A CO-OPERATIVE PROGRAMME OF RESEARCH INTO THE MANAGEMENT OF POME-FRUIT PESTS IN SOUTHEASTERN AUSTRALIA:

I. ECOLOGY

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This programme was pursued jointly from 1966 to 1972 by CSIRO and the entomological services of four States, with the object of (1) investigating the ecology of the entomofauna and (2) evaluating the feasibility of ecology-based control.

Original procedures were developed, which produced an integrated, objective assessment of the status as pests of the main species injurious in orchards. The situation was found to be dominated currently by two key-pests: codling moth, which attains its greatest injuriousness towards the warmer limits of the region; and light-brown apple moth, which is most damaging at higher latitudes and elevations.

The relevant characteristics of both species were defined. Studies on codling moth confirmed the species' ability to persist as very sparse populations and resulted in the construction of a reliable quantified model for the simulation of seasonal activity. The ecology of LBAM was found more difficult to understand. Continuing studies suggest that a pathogen may be playing a determining role in the distribution and abundance of the species.

A CO-OPERATIVE PROGRAMME OF RESEARCH INTO THE MANAGEMENT OF POME-FRUIT PESTS IN SOUTHEASTERN AUSTRALIA: II. REDUCING RATES OF INSECTICIDE AS A FIRST STEP IN INTEGRATED CONTROL

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Good control of codling moth can be obtained with the broad spectrum insecticide azinphos-methyl. But continued use normally results in the development of two-spotted mite as a serious pest, requiring miticide sprays to prevent damage. Natural enemies of the mite, which usually keep it under control, are adversely affected by broad spectrum insecticides.

Field trials were done to find whether reduced rates of azinphos-methyl would maintain good control of codling moth while permitting numbers of the mite's predators to increase.

Over a three-year period, an azinphos-methyl schedule equivalent to one-half of the recommended dosage resulted in very good control of codling moth, but did not permit the mite's predators to survive in effective numbers.

Development of an integrated control programme based on the use of azinphos-methyl at minimal rates would require the implementation of sensitive methods to time codling moth sprays, and to determine objectively when miticidal treatments were needed.

A CO-OPERATIVE PROGRAMME OF RESEARCH INTO THE MANAGEMENT OF POME-FRUIT PESTS IN SOUTHEASTERN AUSTRALIA:
III. EVALUATION OF A NUCLEAR GRANULOSIS VIRUS FOR CONTROL OF CODLING MOTH

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It was recognized that the development of selective, target-specific methods to deal with key pests represented the most important single contribution to orchard pest management. With this in view, a feasibility study was made of a virus as a possible "biological insecticide" against codling moth.

Field investigations showed that the virus had much potential for use in a practical programme of pest management. A number of questions would have to be resolved, however, before the virus were applicable commercially, concerning in particular the residual effectiveness of field applications, industrial production and formulation, and registration for common use.

Similar conclusions were reached by co-workers in the parallel study of a nuclear polyhedrosis virus of light-brown apple moth.

Generally, the Co-operative Programme has revealed that present conditions are not permissive of significant departures in orchard pest control, and that changes in prevailing value-judgements are as necessary as scientific advances for pest management to progress.

ECOLOGICAL PROBLEMS FACING THE ERADICATION PROGRAMME OF *DACUS DORSALIS* (TEPHRITIDAE: DIPTERA) IN THE SOUTHERN ISLANDS OF JAPAN

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The oriental fruit fly is distributed throughout the southern islands of Japan below 29°N. Results of ecological studies based on a recapture technique using Steiner-type methyleugenol traps are reported. (1) Marked flies moved freely between islands. The longest flight was recorded at Chichijima, with the capture of 9 individuals 50 km from Hahajima where they had been released in a cohort of 3,000 marked males. (2) Some males were captured more than 100 days after release, despite the fact that the release point was surrounded by numerous methyleugenol sources. Records indicate that males were often captured after copulation, even at a trap density of 1 per ha. (3) Calculated population parameters showed that the rate of capture in this study ranged from 5 to 20%.

SOME THEORETICAL CONSIDERATIONS ON THE USE OF PARTIALLY-RESISTANT VARIETIES FOR INSECT-PEST MANAGEMENT PROGRAMMES

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Little attention has been paid to the possibilities offered by partially-resistant varieties of cultivars. Using the life-table approach, the methods of controlling pest insects are classified according to their effects on 3 parameters of population increase: development rate, survival rate, and birth rate. According to this classification, an antibiosis-type resistant variety of host plant may affect all 3 parameters simultaneously.

The degree of varietal resistance required for effective protection against an insect pest may be gauged from an integration of the following values: (1) rate of population increase; (2) economic injury level; (3) initial pest density preceding an outbreak; and (4) time elapsing between crop infestation and harvest.

The use of partially-resistant varieties is compatible with all other methods of insect control.

AETIOLOGY OF SOME UNUSUAL INSTANCES OF OUTBREAKS IN POPULATIONS OF INSECTS, WITH SPECIAL REFERENCE TO INTEGRATED CONTROL

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Studies of outbreaks show that population dynamics are affected by a complex of factors, of which one seems generally to predominate in such instances. Primary influences in population outbreaks are:-

- changing cultural practices - particularly intensified production of grain crops and attendant mechanization - in the case of the lepidopterous pests of cereals, *Oria musculosa* and *Cnephasia pumicana*;
- repeated applications of broad spectrum insecticides markedly reducing the abundance of an important parasite, in the case of the leafminer, *Stigmella malella*;
- weather conditions, acting either directly, e.g. to reduce populations of *O. musculosa*, or indirectly, e.g. to impede larval establishment in *C. pumicana*;
- finally, certain glasshouse procedures encourage pest infestations.

Such analyses help to devise rational methods of crop protection in which cultural practices are adjusted to minimize the influence of outbreak-promoting agencies.

THE ECOLOGY OF ORIENTAL FRUIT MOTH *CYDIA MOLESTA* (BUSCK) IN RELATION TO OTHER PESTS OF CANNING PEACHES IN SOUTHERN AUSTRALIA

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The conventional control by chemical insecticides of *Cydia molesta*, the most important pest in the ecosystem of peach orchards, has induced an economic problem with the phytophagous mite, *Tetranychus urticae*. An ecologically-selective method of controlling *C. molesta*, based on the use of non-persistent insecticides against the early spring brood of adults has proved more effective and cheaper to implement than conventional procedures. The new method permits the survival of predacious species, particularly of the *Stethorus* species that maintains populations of phytophagous mites at non-injurious levels.

CHIRONOMUS TEPPERI (DIPTERA: CHIRONOMIDAE) AND AGRONOMIC DEVELOPMENTS IN RICE GROWING

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Larvae of the midge *Chironomus tepperi* Skuse are important pests during the establishment period of irrigated rice crops in the Riverina district of New South Wales. They chew rice seedling roots, enter seeds and remove the endosperm, and uproot seedlings. Significant damage ceases by the end of November but can be severe, and total losses occur where control measures are not taken. Plants from sowings into well prepared seedbeds are generally not damaged severely.

C. tepperi is a widely distributed Australian chironomid midge. Its larva feeds on organic matter within a body's length of the tunnel it builds in the soil. Rice plants within reach are consequently attacked. The development of *C. tepperi* as a pest reflects the change to pasture-rice rotation which provided large quantities of surface organic matter from the pasture phase at time of sowing. In sod-seeded crops populations up to 18,000 larvae per square metre have been noted over extensive areas. Rice will be totally lost from such areas. However, in aerially sown crops pre-germinated seed falls through ponded water to lie on a mat of decomposing pasture. The exposed seed is severely damaged by small populations.

DDT applied to seed has been effective in preventing seedling damage but when added to water has failed in sod-seeded crops. Organophosphate materials are now available as alternative but have encountered similar problems. However, insecticides have enabled agronomic advances to be exploited and remain the current intervention against *C. tepperi*.

PROBLEMS OF THE COMMERCIAL DEVELOPMENT OF INTEGRATED CONTROL

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Integrated pest control involves not only the combined use of chemical and biological means, but also a logical approach to the management of the entire complex of pests and diseases on the crop, requiring the organized cooperation of research workers, advisers, growers, producers of natural enemies, chemical manufacturers, and government departments.

Encouraging progress has been made towards the commercial use of integrated control of glasshouse pests in Britain, particularly employing a system based on the use of *Phytoseiulus persimilis* against red spider mite on cucumbers. Implementing such a system reveals the full complexity of the problems involved. These include the difficulties of importing and selecting natural enemies and testing them for compatibility with other control systems, convincing growers that they must introduce pests in order to control them, and persuading chemical firms to seek approval for the unorthodox use of an insecticide in minute amounts.

NON-CHEMICAL CONTROL OF THE LUCERNE SEED CHALCID, *BRUCHOPHAGUS RODDI* GUSSAKOWSKI (HYMENOPTERA: EURYTOMIDAE)

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This cosmopolitan wasp attacks developing lucerne seeds, often destroying over 70% of the yield. Infestation occurs mainly during May-June, at the time of pod set, which coincides with the flight of adults emerging from the overwintered pupae. Irrigation now allows growers to obtain an additional harvest of lucerne hay and to defer seed production to the July stand. This resulted in reducing seed infestation to below 3%. Success was due to three reasons: (1) the insect has no other local host; (2) adults cannot survive in epidemiologically-significant numbers after 21 days; and (3) growers cooperate on a region-wide scale in preventing lucerne fields from flowering before July, thereby barring the insect from establishing "bridgeheads" early in season. Such non-chemical control measure is of particular advantage in this case, since, unlike pesticidal treatment, it does not harm the insect pollinators or the chalcid's pteromalid parasite, *Habrocytus medicaginis* Gahan.

THE IMPORTANCE OF ALTERNATE HOST PLANTS IN THE MANAGEMENT OF LIGHT-BROWN APPLE MOTH, *EPIPHYAS POSTVITTANA* (WALK.) (LBAM)

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Ecological studies of LBAM are being conducted at two sites: an apple and a pear orchard. At these sites, the moth breeds on 12 other hosts besides fruit trees. Those alternate hosts are all weeds.

The moth population on each of the 12 weeds is dependent to some extent on the ecological succession of the hosts. As the fecundity of LBAM was found to vary with the host plant, the weed composition of the habitat would be a factor determining the abundance of the insect. There is evidence that temporal differences in fecundity are related in fact to weed succession. LBAM is a polyphagous pest without an obviously-preferred host. The species is likely to be more abundant outside orchards than in them, and selective weed control in orchards may not necessarily be of great value *per se* in the management of pests of this type.

THE EUROPEAN CORN BORER (*OSTRINIA NUBILALIS* HÜBN.) (ECB) IN ALSACE (FRANCE). EFFECTS OF INFESTATION, DAMAGE ASSESSMENT, INJURIOUSNESS, AND CONTROL

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ECB is a serious pest of maize. Crop losses caused by the pest result in equal parts from loss of grain weight induced by undersupply of nutrients to the ears following stem breakage, and from the failure of mechanical harvesters to retrieve ears from the ground.

A method has been developed to estimate crop losses from records of the frequencies and forms of injury sustained, based on prior measurements of damage actually caused by ECB attacks. Precise assessments of losses can be made for the varieties studied. ECB infestations sometimes reduce yields by as much as 3 metric tons per ha.

Optimum time for treatment is 21 days after the beginning of the moth flight, or at 50% maturity of the male inflorescences. An oviposition frequency affecting 12% of tillers represents the threshold of economic injury. Control is achieved by means of an insecticide in granulated form.

Chopping up and burning the stubble is effective as a preventive measure.

POPULATION PATTERNS OF *HELIOTHIS ZEA* AND *HELIOTHIS VIRESCENS* - A PROGRESS REPORT

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A team approach is used to develop a continuing description of *H. zea* and *H. virescens* populations in three large study areas in North Carolina, as a prerequisite to the elaboration of a system of pest management for the two species. Initial efforts are concentrated on the proportionate contributions of maize, soybean, tobacco and cotton to the overwintering cohorts. Ecologically-defined types are distinguished in each of the host plants, and the contribution of each type to the general populations of either species of *Heliothis* is expressed quantitatively. From the population patterns formed, inferences are made about the role of different factors in the population dynamics of the pests and in the suppression of population foci of particular economic concern. These inferences are tested experimentally where possible

CODLING MOTH POPULATIONS UNDER NATURAL, INTEGRATED, AND CHEMICAL CONTROL IN NOVA SCOTIA

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Codling moth populations on volunteer apple trees scattered throughout Nova Scotia are compared with those in commercial orchards. Failure of crop, degree of isolation, amount of crowding by native trees, and natural enemies determine the abundance of codling moth in wild fruit. Young commercial orchards require artificial control shortly after they begin to bear to prevent heavy loss of crop. An occasional assist by chemical treatment is sufficient, however, to contain the codling moth below economically-tolerable levels in older orchards. Such treatments are applied so as to interfere as little as possible with natural agents of control. The pest is highly susceptible to all common insecticides and shows no indication of tolerance. The sex ratio of codling moth can be used as an indicator of population trends.

INFLUENCE OF ETHYL AND METHYL PARATHION ON PARASITOIDS OF *PHYTOMYZA ATRICORNIS* MEIGEN (DIPTERA: AGROMYZIDAE) IN ARTICHOKES

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The chrysanthemum leafminer, *Phytomyza atricornis* Meigen, is a secondary pest of the globe artichoke, *Cynara scolymus* L., in California. The primary pest of artichoke in this area is the artichoke plume-moth, *Platyptilia carduidactyla* (Riley). A schedule of weekly sprays of either methyl or ethyl parathion is the current means of controlling the moth. But the continuous use of those insecticides causes the leafminer population to reach damaging abundance. Experimentation has shown this effect to result from the suppression of eulophid and braconid parasitoids of the leafminer. The increase in leafminer infestations is more severe in winter months, due to reduced parasitoid activity coupled with more frequent use of parathion. Careful timing of insecticide treatments to avoid killing adult parasitoids seems to be the only solution at present.

THE ROLE OF THE CHEMICAL MANUFACTURER IN THE INTEGRATED CONTROL OF ARTHROPOD PESTS OF CROPS

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Integrated control of plant-feeding insects and mites by the combined use of chemical, biological, and cultural agencies, has been the subject of much research in recent years. Most of this work has been carried out by official institutions in many parts of the world. This paper considers the role which could be played by the chemical manufacturer.

A review of the literature of Integrated Control, and an examination of the large international companies' facilities for screening chemicals and investigating the development of resistance to chemicals in arthropods, suggests three possible approaches.

These are the development of chemicals which would have no residual effect, and could hence be applied to a specific target species; the development of more powerful specific insecticides; and the breeding of populations of resistant predators and parasites which could be released when the particular chemical was applied. The toughest problem confronting the chemical manufacturer in this area is undoubtedly economic. The problem could possibly be solved by some modification of existing patent regulations to encourage this type of research.

STABILITY VERSUS TIME-DELAY IN POPULATION MODELS WITH TWO AND THREE TROPHIC LEVELS

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We consider a general class of models of communities with three trophic levels: resource-prey-predator (vegetation-herbivore-carnivore). It is shown that, under a wide range of conditions which are often fulfilled in nature, this three-level system is quite stable, whereas the two-level vegetation-herbivore system (without predators) is unstable, as is also the prey-predator system, without resource-limitation.

These conclusions can be supported with some observational data. They contrast with earlier, unrealistic theoretical work on time-delays in three-level systems. The model also hints at a reconciliation between the seemingly opposed views expressed in the celebrated controversy between Hairston, Smith, and Slobodkin - and their critics.

OPTIMAL CONTROL OF THE PREY-PREDATOR SYSTEM

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This contribution shows how optimal-control theory can be used to produce optimal strategies for the control of prey-predator systems. Two types of control variables are considered. One is the rate of release of laboratory-bred predators; the other is the rate of application of an insecticide.

An interesting and counter-intuitive result is that it is feasible to control a pest by means of an insecticide that destroys only the predators, but leaves the pest unharmed. This is because the prey-predator system is a dynamical system. The level of the control variable, and the timing of its application, could be manipulated to produce desirable responses from the dynamical system. This fact is relevant to the development of integrated control schemes for the management of a pest.

A STEP IN SIMULATION-ASSESSMENT OF STERILE-RELEASE CONTROL OF LIGHT-BROWN APPLE MOTH, *EPIPHYAS POSTVITTANA* (WALK.) (TORTRICIDAE: LEPIDOPTERA)

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Test populations of light-brown apple moth were established, which contained set proportions of fertile males and of males sterilized by gamma radiation.

It was found that the presence of sterilized males did not reduce the production of viable eggs as much as had been expected. The efficacy of sterilized males was probably reduced in this instance by the reduced competitiveness of sperm from sterilized individuals in females mated with both fertile and sterilized males. Experiments using a radioisotope to identify spermatophores confirmed this inference.

Measurements of mating frequency and other experimental data were integrated in a mathematical model. As well as providing reliable information on the effects of changes in mating frequencies and competitive fitness of sperm, the model made it possible to estimate the degree of impairment in competition with normal sperm, which the sperm from sterilized individuals had suffered.

SYSTEMS SIMULATION IN INSECT POPULATION DYNAMICS AND PEST MANAGEMENT

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We attempt to introduce the general insect ecologist to the uses and advantages of system simulation in the study of insect population dynamics and pest management. The simulation approach is defined, and some of its advantages are discussed, in relation to the more conventional deterministic and stochastic approaches. The rationale of simulation is outlined in terms of simulation objectives, system definition, model formulation, experimentation, and model validation or improvement. Simulation procedures are described using examples from bark beetle population dynamics. A simple simulation model of bark beetle dispersal and host colonization is used to illustrate some elementary simulation techniques, such as random-number generation, cumulative probability distributions, and Monte Carlo methods. The incorporation of a management strategy, in the form of traps baited with pheromones, in the simulation is used to demonstrate the potential of gaming in solving management problems.

COMPUTER SIMULATION OF POPULATION GROWTH AND REGULATION IN *TRIATOMA INFESTANS* (HEMIPTERA: REDUVIIDAE), WITH AN ANALYSIS OF CONTROL STRATEGIES

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Triatoma infestans is the main vector of the Chagas' Disease in many countries of South America. A considerable amount of information about this species (life cycle, population parameters, density effects, and the influence of temperature and insecticides) is available: it was integrated in a computer model to simulate population growth and regulation. An IBM 1130 computer was used to run the model, programmed in Fortran language. The programme was prepared with a view to handling numerical experimentation of the following factors: (1) constant and fluctuating temperature, (2) number and age composition of the initial population, and (3) insecticides. The availability of access to console switches from the programme allowed direct intervention of the experimenter at any moment during simulation, making strategic control decisions possible at any time.

ANALYSIS OF ARTHROPOD DISTRIBUTION BY MEANS OF PRINCIPAL COMPONENT ANALYSIS

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Distributions of species are generally analyzed by studying their abundance along environmental gradients chosen by the investigator. In contrast to this approach, principal component analysis (PCA) reveals the major lines of variation in the distributions of species, so far as they are sampled consciously or unconsciously. The next problem is to find correlations between these major lines of variation (principal components) as shown by the species sampled, and measurable environmental characteristics, selected by the investigator.

Application of PCA in ecology meets two major objections: 1. The environmental characteristics are supposed to operate in an additive way, instead of in a multiplicative way, which is a more realistic assumption. 2. The relation between the density of a species and an environmental factor should be a linear one. However, in general, the relation can be shown to follow an optimum curve.

Logarithmic transformation of the PCA-model removes the first objection. Secondly, optimum curve-like relationships can be shown to result in more than one principal component describing a single environmental factor.

These considerations are illustrated by a field study of the distribution of arthropods in the Dutch coastal dunes.

POPULATIONS OF CITRUS PESTS AND OTHER ASPECTS OF INTEGRATED CONTROL

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Populations of citrus pests vary considerably according to whether they are sprayed with parathion or with "integrated" sprays. Integrated control has been commercially satisfactory in South Africa, and new problems and techniques have been investigated. Certain pests tend to increase when parathion is discontinued, but they often return to a low level of abundance without corrective sprays.

While laboratory tests are valuable, field experiments are essential to test out any new pesticides for integrated control, because all pests and their complex of natural enemies are involved. Pilot experiments with small blocks sprayed one to five times are followed by large blocks sprayed commercially. Abate 500E^R caused a serious increase of several pests in such experiments.

Integrated control demands a new outlook on pest control. A detailed cost/benefit approach shows that expenditure on pest control can be reduced by half or more. Integrated spray programmes must be planned for each different citrus area.

REDUCTION OF MEALYBUG POPULATIONS IN VINEYARDS IN THE WESTERN CAPE PROVINCE, SOUTH AFRICA

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The Argentine ant *(Iridomyrmex humilis)*, imported accidentally in 1900, is undoubtedly the main reason for the mealybug, *Planacoccus citri*, attaining pest status on table grapes in the Western Cape Province.

Local natural enemies, mainly the coccinellids, *Nephus angustus* and *Nephus* sp., readily attacked this mealybug, but populations remained above economic levels. Removal of the Argentine ant, by application of dieldrin to the soil or vine stems, increased predator numbers, and the mealybug population was depressed to sub-economic levels within six months in most areas. In one inland valley, however, elimination of ants did not solve the mealybug problem. Bioassays showed that the fungicide dust diluents, kaolin, talc, and sulphur, were toxic to adult coccinellids.

Mass releases of predators and manipulation of the fungicide programme has indicated that this approach can contribute to a reduction in mealybug numbers.

RYANIA FOR MANAGEMENT OF A UNIVOLTINE CODLING MOTH POPULATION *(LASPEYRESIA POMONELLA* L.)

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The selective insecticide ryania has been applied since 1962 against the codling moth in an Integrated Programme for the control of orchard pests at Nelson, New Zealand.

Despite the relatively low toxicity of ryania, life tables established over five years, at densities of one to six females per tree, have shown that ryania was capable of causing trend indices consistently smaller than 1 in this univoltine population, whereas values greater than 1 obtained in the absence of ryania.

A simulation of the response of the population to ryania takes account of the deposition and degradation of the material, particularly by rainfall, in relation to larval entry into the fruit.

The aim of the simulation and life tables is population management, particularly through increased understanding of the action of ryania, and ultimately by providing predictive assessment of the population under a continuing ryania programme.

FACTORS INFLUENCING THE INTEGRATED CONTROL OF LIGHT-BROWN APPLE MOTH, *EPIPHYAS POSTVITTANA* (WALK.) (LEPIDOPTERA: TORTRICIDAE)

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The light-brown apple moth, an immigrant from Australia, passes through three generations annually in the central New Zealand region. Populations of this extremely polyphagous insect surviving within pome-fruit orchards are attacked by a complex of predators and parasitoids, which differs markedly from its counterpart in eastern Australia.

Successful introduction and establishment of 4 Australian parasitoid species has been achieved during the period 1967 to 1972. Simple rearing techniques for the host has enabled mass-rearing of parasitoid species, also the production of a nuclear polyhedrosis virus. Within the orchard monoculture, environment modification has provided suitable overwintering, and summer feeding, niches for the parasitoids.

Analysis of life-table data has shown that extensive mortalities occurred during certain age intervals.

APPROACHES TO A COMPLETE COTTON INSECT MANAGEMENT SYSTEM: I. HOST PLANT RESISTANCE STUDIES AND EFFICIENT SAMPLING TECHNIQUES

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A system of pest management for cotton, centred around new, agronomically-sound strains of semi-glabrous nectariless Acala cottons, has been under development at New Mexico State University for several years. Results indicate a decrease in bollworm oviposition rate of about 74%, and an increase in cabbage looper oviposition rate of about 28%. Successful implementation of a total system, however, depends on the development of fast, inexpensive ways of accurately measuring insect populations and the factors that control their numbers. Sampling has been simplified by mounting an hydraulically-controlled large-volume fan on a high-clearance tractor. The machine blows air across cotton plants into a collecting net at a velocity of about 70 miles an hour. This device adequately solves the collection problem, but it emphasizes the need for a fast accurate counting instrument.

APPROACHES TO A COMPLETE COTTON INSECT MANAGEMENT SYSTEM: II. THE CONSTRUCTION OF AN AUTOMATIC LARGE-SCALE INSECT IDENTIFICATION AND COUNTING SYSTEM

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The automatic system scans a 17.5 x 17.5 inch area on which up to 5,000 cotton insects have been placed. A light-intensity measurement is made every 0.0175 inches in the three primary colours, red, blue, and green. The garnered data are "digitized" and "formatted" by a computer for storage on a disc memory unit. One million data-words are generated in the course of one scan. At the completion of the scanning process, the stored information is processed by the computer to determine the size, shape, and colour of the individual insects placed on the table, and is then subsequently compared to previously stored patterns for identification. A printed total of the different species seen, and their respective numbers, completes the scanning process. The time for the completion of scanning and identification of one batch of 5,000 heterogeneous field-collected insects is just under one hour.

THE ECONOMICS OF OVERKILL

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The benefit that insecticides have brought to mankind stands as a testimonial to technological advancement in terms of lives saved, diminished suffering, and economic gain. But the blessing is not an unmixed one: it has created serious problems inasmuch as ecological considerations were largely ignored in the development and implementation of chemical pesticides. "Overkill" of arthropod populations has long been the accepted philosophy of farmers demanding insect-free crops, and, implicitly, of the consuming public conditioned to expect blemish-free produce. Evaluations of chemical insecticides have frequently failed to determine acceptable rules for industrial usage. Chemical insecticides are distributed commercially like ordinary market goods, and the fine products of laboratory scientists are often turned over for field use to inadequately-trained personnel.

ECONOMIC ASPECTS OF PEST MANAGEMENT STRATEGIES AND DECISIONS

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Pest management strategies may be considered on a topical (e.g., farm), or on a regional scale. Topical decisions can affect regional parameters such as pest abundance, resistance to insecticides, and availability of natural enemies.

Topical decisions about pest management rest on knowledge of the costs of control and of expected crop returns. At regional level, other considerations such as pollution of ecosystems, development of resistance, and impact on natural enemies and non-target organisms, should be considered. But programmes based on these criteria would seldom maximize short-term yield returns, and their adoption often has to await the development of adverse regional trends such as resistance or secondary pests.

Thus, pest management strategies that are optimal according to the farmers' criteria may not be optimal from the regional viewpoint, and Governments may be justified in using subsidies, taxation, education, etc., to promote adoption of regionally-acceptable procedures.

INTEGRATED CONTROL OF INSECT PESTS ON CITRUS FRUITS IN VICTORIA, AUSTRALIA

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Integrated control of red scale has been successfully achieved in northern Victoria. Of five species of hymenopterous parasites released, three have become abundant on properties where the use of broad spectrum insecticides was abandoned, and where only white oil was used in critical situations. The populations of both host and parasites are monitored throughout the year by means of samples from five areas. It is planned to introduce more species of exotic parasites to reinforce existing agents. Chemicals other than white oil are being evaluated for use in integrated programmes.

Other pests under biological control are: cottony cushion scale, black scale, soft brown scale, and citricola scale. In these instances also, control by natural agents can be upset following destruction of non-target organisms by broad spectrum insecticides.

CITRUS INSECT CONTROL IN TAIWAN AND A NEW INTEGRATED CONTROL METHOD

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The history of citrus pests in Taiwan, and their control, are reviewed briefly. Yanone scale has been eradicated since its discovery in 1935, and other citrus pests have been controlled satisfactorily during the last 15 years by chemical means. Recently however, citrus red mite has become unusually abundant, and resistance to most acaricides was recorded.

Azodrin applied to the trunk twice during both second and third growth-flushes will control most species of aphids, mealybugs, scales, stink bugs, leafminers, and rust-mites. This method was used successfully for four years in the treatment of 1,000 citrus trees, without any serious effect on the complex of beneficial insects, and citrus red mite was well-controlled by two predatory beetles.

POPULATION MANAGEMENT OF THE FRUIT-SUCKING MOTH, *OTHREIS FULLONIA* (CLERCK) (LEPIDOPTERA: NOCTUIDAE), IN NEW CALEDONIA

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After severe drought in New Caledonia, large infestations of *Othreis* larvae can occur in the coastal plains, because the activity of an egg-parasite, *Ooencyrtus* sp. (Encyrtidae), fails to coincide with heavy oviposition by the moth. The adults of these initial outbreak populations disperse along the coast or up the mountain valleys, spreading the infestation while searching for fruits to suck.

It was possible to prevent egg-laying, and thus avoid the development of a second generation in the uplands, by locally destroying the moth's obligatory host-plant, *Erythrina* (Leguminosae). Invading females were turned away by the lack of oviposition sites, and males may have followed. A good crop of mandarines was produced thereafter in the treated area, whereas losses approached 100% elsewhere.

The same experiment is being conducted on a large scale in the Loyalty Islands (Lifou).

INTEGRATED PEST CONTROL AND PASTURE PESTS IN NEW ZEALAND

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The present paper outlines some of the attempts that have been made to utilize biological, cultural, and chemical control, assisted by infra-red aerial photography and by bio-meteorology, for the control of grass grub, *Costelytra zealandica*, and porina moth, *Wiseana* spp., the two worst pests of pastures in New Zealand.

PRACTICAL PROBLEMS IN THE IMPLEMENTATION OF INTEGRATED CONTROL IN SOUTH AFRICA

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The deciduous-fruit industry in South Africa is strongly export-oriented. As fruit sorting is mechanized, the numbers of damaged fruits resulting from integrated control can cause expensive delays. Of the more serious pests, red spiders, mealybugs, scales, and woolly aphid lend themselves to integrated control, because population increases can be recognized well before the fruit is endangered. This does not apply to codling moth and fruit flies which can cause 80-95% crop losses in unsprayed orchards: even small numbers of the latter species can cause economically serious infestations.

The lack of suitable specific insecticides to combat such a wide complex of insects presents a problem. Some of the pests may disappear under integrated control, but sporadic pests such as boll-worm may upset a delicately-balanced programme.

The continuing surveys necessary for integrated control, and the high cost of insect damage where the programme fails (especially during the early stages) are equally daunting, but not insuperable, difficulties.

PRESENT STATUS OF INTEGRATED CONTROL OF ORCHARD PESTS IN THE NETHERLANDS

P. Gruys, M. van de Vrie, D.J. de Jong and A.K. Minks

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In 1970, a normal spraying programme in Dutch pome-fruit orchards included 5 sprays of insecticides, 2 of miticides, 16 of fungicides against apple scab and Gloeosporium, and 7 against powdery mildew.

Resistance to miticides in the European red mite poses a major problem. The introduction of predatory mites for the control of this pest is therefore one of the main projects of the Working Group. In this connection, more study is needed of the application of selective insecticides, e.g., of *Bacillus thuringiensis* against lepidopterous larvae, and of mineral oils and pirimicarb against winter eggs of European red mites, aphids, and the green capsid, *Lygus pabulinus*. It is essential also that the side-effects of fungicides like dodine, captan, dinocton-4, and thiophanate be evaluated.

Current sampling methods and estimates of economic thresholds of infestations are satisfactory.

In 1972, an integrated control schedule is being tested on about 20 acres of orchards, and supervised control using broad spectrum insecticides at minimal rates is being applied in 25 commercial orchards totalling 125 acres.

INTEGRATED CONTROL IN DENMARK

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Methods of integrated pest control have been used for many years in Denmark, and new ones are being developed. A few examples are mentioned.

Frit fly was formerly a major pest of cereals, but has lost much of its injuriousness since farmers have learned to sow oats and barley early in spring, and to plow grassland in time before sowing rye and wheat in autumn.

Boundary treatments of rape fields against *Dasyneura brassicae* and *Meligethes* spp., or of swede and cabbage fields against *Contarinia nasturtii*, are now standard, in preference to whole-field treatments.

The control of aphids involves population surveys of natural enemies, and systemic compounds are often used to conserve beneficial insects. Similar methods are being developed for other pests.

PEST MANAGEMENT STUDIES IN FRANCE

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The organization, procedures, and overall results of the work done in France are discussed and illustrated with particular reference to pests of apple and peach orchards, and to greenhouse pests.

THE ROLE OF BIOLOGICAL CONTROL IN PEST MANAGEMENT

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The concept of "biotechnical control" is defined as a practical compromise between technological and biological methods, and briefly illustrated.

After discussing current research on biological control in Germany, attention is centred on cases where benefits and costs cannot be measured in solely economic terms. Neither the life-saving results of vector control, nor the protective and social value of silviculture and agriculture in densely populated regions, can be valued in money. Nevertheless, the need for less expensive measures of integrated control is believed likely to increase in future. This will include instances in which medical and ecological constraints are compelling, and where agriculture becomes part of conservation.

PHILOSOPHY AND FEASIBILITY OF INTEGRATED CONTROL

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The revolution in pest control ushered in by the discovery of the insecticidal properties of DDT has created a situation in which Integrated Pest Control has become essential. There are now many instances of pest species becoming resistant to an insecticide after losing their parasites because of its use. Parasites which survive an insecticide application may not find hosts after the treatment: while pests are exposed to one hazard only, parasites face a double jeopardy, both from the indirect effects and from the direct action of the insecticide. Pests have, therefore, a much greater chance to survive and become resistant than parasites.

Integrated control is more efficient and cheaper than conventional methods. It avoids, or at least delays, the development of resistance to insecticides, and it minimizes residue problems. In many cases it is also more practical than conventional methods. A number of case histories will be cited.

STRATEGY IN THE INTEGRATED CONTROL OF RICE PESTS

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The use of technical BHC against *Chilo suppressalis* triggered the upsurge of *Nephotettix cincticeps* by killing the latter's natural enemies, and precipitated the development of insecticide resistance in the leafhopper. Changing the formulation of BHC from dust to granule form was no improvement, because of BHC's action through the food-chain.

The success of biological control by either introduced or native natural enemies was limited by the fact that the paddy fauna is composed of endemic species. The possible value of varietal resistance in a programme of integrated control is limited also, because *japonica*-type rice is especially susceptible to leaf- and planthoppers. The current approach is, therefore, to minimize the frequency and dosage of insecticidal treatments, and to encourage the recovery of natural enemies by using selective insecticides.

A preliminary computer-simulation of the leafhopper-spider-insecticide system suggests that populations of leafhoppers may be managed successfully in this way.

ECOLOGY OF TWO SPECIES OF RICE PESTS IN RELATION TO THEIR CONTROL

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Nephotettix impicticeps Ishihara and *Nilaparvata lugens* (Stål) are important and widely distributed pests of rice in the tropics, that are immediately injurious to the plants as well as transmitting virus diseases. So far, control measures have been applied against them only when damage or disease has become evident. Recent research in the Philippines indicates that programmes of integrated control based on an understanding of the ecology of those species may contain populations at sub-injurious densities. The implementation of these programmes requires a knowledge of population composition, fluctuation, and behaviour; of predators and pathogens; of seasonal effects; and of various agronomic factors. The appropriate degree of protective management to be achieved varies according to the probable incidence of virus disease. Major difficulties to be overcome in the application of integrated control in tropical rice farms are: forecasting probable damage; assessing the limiting effects of natural enemies and insecticides; and educating the farmers.

INTEGRATED CONTROL SCHEDULE FOR THE IMPORTANT PESTS OF SORGHUM

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Recent data indicate that the new high-yielding hybrids and varieties of sorghum are very susceptible to insect pest attack. Appreciable losses by three major pests, the shootfly (*Atherigona varia soccata* Rand.), the stem borer (*Chilo zonellus* Swin.) and the midge (*Contarinia sorghicola* Coq.) have been reported.

Because sorghum is not as lucrative a crop as paddy or cotton, its pests must be controlled by procedures of integrated control. It is now possible in India to develop methods involving cultural techniques and host plant resistance, which can be integrated with the judicious use of insecticides, and which also permit maximum benefit from natural agents.

The paper presents some significant results to serve as a basis for a schedule of integrated control.

AN INTEGRATED PROGRAMME FOR THE SUPPRESSION OF LESSER CANNA LEAFROLLER IN THE SOUTHEASTERN UNITED STATES

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Lesser canna leafroller, *Geishna cannalis* (Quaintance), is a serious pest of several hybrids of *Canna lutea* grown as ornamentals in the southern United States. The infested plants produce whip-like central shoots, and usually fail to flower. Efforts to control the larvae with conventional contact insecticides were not very successful. But, of the systemic insecticides tested, methomyl and Orthene^R gave almost complete control with three foliar applications during the growing season. Trichlorfon-oxydemeton methyl also provided an acceptable degree of protection. Data on the host specificity, dispersal, and overwintering behaviour indicate that a systematic, area-wide disposal of dead canna plants (during the winter), followed by proper use of an effective insecticide (during the growing season) should practically eradicate this pest from large areas in the United States. Detailed plans of the project will be presented.

AN APPROACH TO INTEGRATED CONTROL OF ORCHARD MITES AND THE TORTRICID *EPIPHYAS POSTVITTANA* IN SOUTHERN AUSTRALIAN ORCHARDS

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The use of broad spectrum insecticides such as DDT, and then azinphos-methyl and carbaryl, for codling moth control in orchards has created problems with other pest species, because of the effect of those materials on beneficial species.

In Tasmania and southern Victoria, tetranychid mites and light-brown apple moth *(E. postvittana;* LBAM) have become major pests in apple orchards, and control of the latter is at present achieved by sprays applied at 14 days' intervals. A continuing search has been carried out for materials which will control both codling moth and LBAM without harmful effects to natural enemies of the moths and of phytophagous mites.

With the introduction of the specific material, *Bacillus thuringiensis*, the number of applications of broad spectrum insecticides can be reduced from 8 to 4 by alternating an insecticide with the pathogen. It is hoped that programmes of this type will encourage the re-establishment of beneficial species in orchards.

Furthermore, the new material, leptophos, has proved to be only moderately toxic to *Stethorus* spp., considered to be one of the main predators of orchard mites, while it also equals the present standards of control of both codling moth and LBAM.

A beginning has been made to use both chemical and biological agents in control of orchard pests, and it is predicted that further use of more selective methods may be expected.

THE STRATEGY OF PLANT PROTECTION AGAINST PESTS IN AGRICULTURE AND FORESTRY

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In a planned economy, plant protection calls for a strategy of pest control in which preventive and curative methods are harmoniously combined. This paper discusses such a strategy in terms of its economic, technical, and biocoenotic aspects.

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SECTION NO. 10

TOXICOLOGY, RESISTANCE AND SIDE EFFECTS OF INSECTICIDES

CONVENOR: J.T. SNELSON

MODE OF ACTION OF FORMETANATE AND FORMPARANATE ACARICIDES

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The mode of action of formetanate and formparanate was studied in the white rat, house fly *(Musca domestica* L.*)*, and two-spotted mite *(Tetranychus urticae* Koch*)*. Both acaricides were highly toxic to the animals. The intraperitoneal LD$_{50}$ to rats was 4.7 and 4.1 mg/kg for formetanate and formparanate, respectively; the injected LD$_{50}$ to house flies was 4.0 and 4.7 mg/kg for formetanate and formparanate, respectively; and the contact LC$_{50}$ to spider mites was 7.5 and 8.0 p.p.m. for formetanate and formparanate, respectively. The two compounds also were relatively potent inhibitors of cholinesterase *in vitro* yielding pI$_{50}$ values ranging between 5.0 and 6.9 for whole homogenates of rat brains, house fly heads, and spider mites. Moreover, cholinesterase inhibition *in vivo* in the organisms treated with formetanate was reasonably well correlated with symptoms of poisoning. Thus, it is concluded that inhibition of cholinesterase is the fundamental lesion produced in animals poisoned by these acaricides.

RABON^R AS A CATTLE FEED SUPPLEMENT FOR FLY CONTROL

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Rabon^R, 2-chloro-1-(2,4,5-trichlorophenyl) vinyl dimethyl phosphate, was incorporated into a protein supplement and fed at 50 p.p.m. in the total ration of beef and dairy cattle on pasture and in feed lots. Field and laboratory tests show that this method of administration to cattle prevents development of larvae of *Musca domestica* L., *M. autumnalis* DeG., *Stomoxys calcitrans* (L.), and *Haematobia irritans* (L.) in the resultant feces. Many other dung inhabiting arthropods survive the treatment. Reduction of fly populations on and around the cattle was dependent upon habits of the specific flies and degree of isolation of treated animals from other sources of flies. *M. autumnalis* populations were least affected because of rapid reinfestation from untreated animals. *H. irritans* was well controlled by the treatment. Supplemental treatment by other modes of application will be necessary to maintain control of the fly complex.

ACTIVITY OF COMPOUNDS DESIGNED ON A THEORY OF DDT MODE OF ACTION

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The compounds used in this study were produced by G. Holan (CSIRO) on the basis of a theory of DDT mode of action on insect nerves, i.e. interference with the permeability of the axon membrane to ions. The compounds are similar in dimension and stereochemical configuration. The insecticidal activity of these compounds was initially determined using the WHO susceptible strain of houseflies. Their relative effectiveness has also been determined for a number of genetically defined housefly strains containing resistance factors, with special emphasis on the kdr factor. The action of these compounds on selected nerves of houseflies and cockroaches has provided additional evidence to support Holan's theory of mode of action.

R-20458 A PROMISING NEW JUVENILE HORMONE ANALOG

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The ongoing search for selective substances to manage noxious insect populations has yielded several promising approaches.

One challenging approach is the possibility of managing insect pests by causing derangement of their growth processes with juvenile hormone analogs (JHA).

In the course of our own studies in this field we have discovered and are actively developing a very promising JHA, namely R-20458, 1-(4'-ethylphenoxy)-6,7-epoxy-3,7-dimethyl-2-octene.

Preliminary biological evaluations indicate promising growth and development disruption effects in economically important dipterous insects including mosquitoes and biting flies. Other potentially practical areas include management of stored product insects.

Environmentally, R-20458 shows short-to-moderate persistence as measured by hydrolytic, photolytic and atmospheric stability.

It is non-acutely toxic to higher non-target animals, and preliminary metabolic studies in the rat show that R-20458 does not accumulate in rat tissues and is rapidly excreted as terminal, inactive biotransformation products. It appears that R-20458 may find significant utility in developing integrated control programs.

PYRETHRUM AS A STOMACH POISON

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Symptomatological, histopathological and histochemical observations reveal that pyrethrum cannot be discarded completely as a stomach poison. The early symptoms recorded soon after oral administration of pyrethrum are similar to those observed when it is applied as a contact poison, suggesting the effect on the nervous system through the innervation of the alimentary canal supplied with the nerves from stomodeal nervous system. Based on histopathological observations, the order of effect on the alimentary canal is mid, fore and hindgut. The effects on midgut include cytoplasmic vacuolisation condensation of chromatin of nuclei, hypersecretion and increase in the rate of replacement of epithelial cells by regenerative cells of the nidi. Histochemical studies show effect on carbohydrate non-specific phosphatases, glycogen and phospholipid activities which are expected to cause disturbances in certain physiological aspects such as transport of solutes, protein synthesis, and food reserves. It may be concluded that on oral administration, the effect is cumulative, i.e. on the nervous system and the alimentary canal.

THE EFFECTS OF SOME NEWER PYRETHROIDS ON THE ARMYWORM, *SPODOPTERA LITTORALIS* (LEP.) AND SOME OTHER PESTS

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A number of workers have demonstrated the insecticidal activity of 5-benzyl-3-furylmethyl (+)-*trans*-chrysanthemate (bioresmethrin) and the corresponding (±)-*cis-trans* ester (resmethrin). This paper reports on the toxicity of these compounds to two strains of the armyworm, *Spodoptera littoralis*, and to the migratory locust, *Locusta migratoria*, and the Australian plague locust, *Chortoicetes terminifera*.

Acetone solutions of the pyrethroids were applied topically in 2.0 µl doses to the thoracic terga of 4th and 5th instar armyworms: with other species 1.0 µl drops were placed on the first abdominal sclerite. Synergists were applied in combination (10:1 w/w) with the insecticides.

Both compounds were toxic to parathion resistant and parathion susceptible strains of *S. littoralis*, with LD_{50} values of approximately 1.0 μ g/g after 48 hr exposure. Resmethrin was slightly the more toxic and this contrasts with other reports on the relative toxicities of these compounds. A factor of synergism of between 3 and 6 (depending on exposure time) was obtained for resmethrin in combination with sesamex against the parathion susceptible strain.

Preliminary results with the locusts indicate that bioresmethrin is toxic to both species and, based on LD_{50} values obtained after 96 hr exposure, *L. migratoria* (1.0 μ g/g) was more susceptible than *C. terminifera* (4-6.0 μ g/g).

THE USE OF LOGARITHMIC ISOBOLES IN ASSESSING THE COST AND EFFICIENCY OF MIXTURES OF INSECTICIDE PLUS SYNERGIST

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The term isobole is applied to the plot of dose of insecticide against dose of synergist, at a selected level of response. Logarithmic transformation of both scales is of particular value in condensing the isobole and in producing a near linear relationship over a wide range of mixtures.

A logarithmic isobole may be used simply to indicate the range over which synergism occurs and to select the cheapest mixture for a given response.

In flysprays, efficiency depends upon satisfying requirements for both knockdown and kill. Separate isoboles may be drawn for both responses and these can be used to select appropriate blends.

The method has been extended, using mixtures of two synthetic pyrethroids with a synergist and a computer-based mathematical model substituted for the graphical method. This may be interrogated to obtain the predicted performance values of any mixture and so allow cost and efficiency comparisons to be made.

EFFICACY OF NEW PETROLEUM DERIVATIVES DEVELOPED FOR MOSQUITO CONTROL

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Several recently developed petroleum hydrocarbons which are virtually non-toxic to fish, wildlife, and humans, have been evaluated both in the laboratory and in the field. Applications to the water surface at the rate of 1 gal/ac and ½ gal/ac produced virtually complete mortality of *Aedes taeniorhynchus*, *Culex pipiens fatigans*, and *Aedes aegypti* larvae and pupae, respectively. The same level of control of *Anopheles quadrimaculatus* and *Anopheles albimanus* larvae and pupae was obtained at dosage rates of ½ and ¼ gal/ac, respectively. Topical applications of 0.2 μl were lethal to the adults of these species.

These petroleum derivatives were found to interfere with normal respiration rather than producing death through direct toxic action like conventional insecticides. Heavy larval selection pressure maintained for more than six years has not led to any change in susceptibility of *Culex p. fatigans*.

Highly organic phosphate resistant field populations of vector and non-vector species were controlled by applications of 1.25 to 3 gal/ac.

CHLORPYRIFOS CATTLE LOUSE OVICIDE

R.S. Buchanan

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In New Zealand diazinon requires two spray applications at 250 p.p.m. to successfully control lice on cattle. The second application at 14-21 days after the first kills nymphs emerged from eggs that were present and unaffected at the first application. In field trials chlorpyrifos sprayed at 250 p.p.m. was found to give the same level of control in one application. Laboratory observation of louse eggs sprayed in field trials and measurements of subsequent nymph hatching showed chlorpyrifos killed the eggs. In addition, louse challenge testing of sprayed animals showed chlorpyrifos to be sufficiently residual in the coat to kill nymphs emerging from eggs that might escape initial contact treatment.

1-(2,6-DISUBSTITUTED-BENZOYL)-3-(PHENYL)-UREAS, A NEW GROUP OF INSECTICIDAL COMPOUNDS

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N.V. Philips-Duphar, "Boekesteyn", 's Graveland, The Netherlands

Abovementioned compounds have good insecticidal activity on the larval stages of many economically important insect species; adult insects are not affected. As the compounds are stomach poisons with neither contact- nor systemic action, the larvae of certain groups of insects will escape treatment, such as sucking insects and acari, borers, miners, etc. For the same reason many parasites, predators and harmless insects are safeguarded.

The compounds have shown very encouraging results on mosquito larvae, fly larvae in maure and chicken litter and various leaf feeding insect larvae in forestry and agriculture.

Larvae which have ingested these compounds have difficulty in moulting or pupating, resulting in death. Until then the larvae behave and feed normally. Treatment of early instar larvae therefore should keep crop damage to a minimum.

CORRELATION OF DDT USE IN CALIFORNIA WITH DECLINE OF PACIFIC SARDINE, *SARDINOPS CAERULEA* (GIRARD)

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High correlation exists between decline of catch of Pacific sardine and increase in use of DDT in California.

Evidence to support a hypothesis of cause and effect includes:

1. High toxicity of DDT to many species of fish and fish food organisms.
2. Known accumulation of DDT in sardine tissues.

3. High oil content of sardines (DDT is oil soluble and accumulates more in oily fish than in others).
4. Established ability of DDT to inhabit reproductive success of fish.
5. Major water run off from agricultural land in California introduced to area of first decline of sardines.
6. Decrease in survival ratio of sardines indicating some environmental adversity other than only overfishing. (Overfishing should increase survival ratio of young).

These data do not prove cause and effect, however; sufficient evidence fits the hypothesis to question the probability of this occurring by chance alone.

'ARTIFACTS' AND 'MIMICS' OF DDT AND OTHER ORGANOCHLORIDE INSECTICIDES

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A review of world literature reporting the detection of extraneous substances in nature (artifacts) and a synthetic compound (mimic) that give identical retention times to those of DDT and certain other organochloride insecticides when analyzed with gas-liquid chromatographic-electron capture procedure, including chromatograph charts obtained by GLC analysis of pre-DDT origin soil and animal tissue, showing the presence of such artifacts.

THE UPTAKE AND DISTRIBUTION OF DDE BY *CHIRONOMUS TENTANS* FABRICIUS AND ITS EFFECT ON EGG VIABILITY

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The midge, *Chironomus tentans*, was exposed from egg through adult to varying concentrations (0.07-2.2 p.p.b.) of DDE. The accumulation of DDE from aqueous solution by the midge as a function of DDE concentration and exposure time was determined and the distribution of the accumulated DDE residue was quantitated (pupa, exuvia, adult, and egg mass).

The DDE accumulation by the midge demonstrated a dose-dependent relationship, accumulating DDE exponentially with increased concentration at a given exposure time. At any given concentration of DDE in the water, accumulation increased with increased exposure time. On a p.p.m. basis the midges concentrated DDE approximately 20,000 times over that level which was present in the water.

The exuvia did not demonstrate a major route of residue elimination as only 1.4-4.9% of the pupal burden was lost via the exuvia. The process of egg deposition eliminated 11.6-30.9% of the adult female burden of DDE residue. There was a significant reduction in the number of adults emerging from these DDE treated egg masses.

THE EFFECT OF INSECTICIDES ON THE SOIL AND PASTURE FAUNA

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A pasture near Nelson, New Zealand, was treated on 3 May 1971 with 4 insecticides to see what effect these chemicals have on all components of the soil and pasture fauna and on micro-organism activity, pasture yield and the soil. The four chemicals used were DDT, fensulfothion, fenitrothion and carbofuran.

During each sampling period, four sets of samples were taken for estimation of the fauna. Earthworms and large arthropods were separated from the 40-60 mm profile by salt flotation (Hollick). Small arthropods were separated from the 0-30 mm and 30-60 mm profiles by dry heat extraction. Enchytraidac and diptera larvae were recovered from the 0-30 mm and 30-60 mm zones by a wet funnel heat extractor while nematodes, rotifers and tardigrades were recovered from the same zones by sugar flotation.

The sites were sampled during April, the month before treatment, and after treatment in June, September and November. Sampling will continue for a further 2 years.

ENVIRONMENTAL FACTORS AFFECTING THE DEGRADATION AND INSECTICIDAL EFFICACY OF CHLORPYRIFOS (DURSBAN^R)

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and R.C. Hunter

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Chlorpyrifos, 0,0-diethyl 0-(3,5,6-trichloro-2-pyridyl) phosphorothioate, is a broad spectrum insecticide whose length of residual insecticidal activity under field conditions varies greatly. Under certain conditions its residual life is quite long; under others it is quite short. The rate of degradation is associated with the environmental conditions to which the chemical is subjected. In all cases the chemical degrades to naturally occurring organic compounds.

Results of detailed studies on the effect of principal environmental factors on the rate of degradation of chlorpyrifos are discussed and these data are related to the insecticidal performance of the compound.

ENVIRONMENTAL FACTORS AFFECTING THE FATE OF PESTICIDES

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Pesticidal chemicals are deposited onto soil after the application to plants or after being applied directly to soils for the control of various soil pests. Once they end up on or in the soil, a variety of physical, chemical and biological factors affect their dissipation, resulting finally in a residue consisting of either the originally applied parent compound, various of its metabolites, or both. Since these synthetic agricultural chemicals are exposed to different environmental factors at different times, the microclimate of a particular area plays an important role in these matters. It is evident, therefore, that it is impossible to attribute an absolute life time or "half life" to any of these chemicals. Dependent on the environmental conditions, they may be of relatively short persistence or may be detectable for a relatively long time.

In this presentation the fate of some insecticidal chemicals after their usage for insect control will be discussed. Environmental factors such as soil types, water, soil microorganisms, climatic conditions, agricultural practices, etc. are examined relative to their effects on the persistence, movement and metabolism of insecticides. In addition, some of these conditions affecting the penetration and translocation of insecticides into and in crop plants - grown in insecticide contaminated soil - will be described. Interactions between detergent, polychlorinated biphenyl plasticizers (PCBs) in soils and insects are described, indicating that the biological activity of some of these non-insecticidal chemicals should not be disregarded. The potential mode of action of PCB's in blocking the enzymatic detoxification of insecticides in insects, thus increasing their toxicity, will be discussed.

PROSPECTS FOR SUBSTITUTION OF DDT BY LESS PERSISTENT INSECTICIDES IN FOCI OF SOME NATURAL INFECTIONS OF HUMAN DISEASE

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One of the important problems of medical parasitology is to find insecticides to replace DDT and develop methods of using new preparations which have high toxicity to ticks and insect vectors of infections but which exert a less fatal influence on biogeocenoses. Investigations were carried out in foci of tick-borne encephalitis in the south taiga and in plague enzootic areas of the Alpine stony steppe. The area of experimental plots made up 2 100 ha.

In foci of tick-borne encephalitis the organophosphorus compounds Trichlophos, Carbophos, Methnitrophos, Methation were found to be the most promising. All stages of the tick *Ixodes persulcatus* L. were killed by these preparations which were applied in the form of 0.5-1% water emulsions. All were less lethal than DDT to useful soil-forming invertebrates. In plague-enzootic areas, mixtures of Sevin with pivalyl were effective against fleas *Ceratophyllus tesquorum* Wagn., ticks *Dermacentor nuttalli* and the Mongolian pika *Ochotona pricei* Thomas.

RESISTANCE TO INSECTICIDES IN COCKROACHES - PRESENT SITUATION, AND REPRODUCTIVE AND MORPHOLOGICAL COMPARISONS BETWEEN STRAINS

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Resistance in wild populations of the German cockroach in the U.S.A. has remained at low levels to organic phosphates, and at moderate to high levels to organo-chlorine compounds, with little apparent change in recent years.

Comparative reproductive studies resulted, in most cases, in lower numbers of: egg cases; nymphs per egg case; and total nymphs in malathion- and diazinon-resistant strains than in normal strains. This is in accord with data previously obtained from organo-chlorine resistant strains.

Comparisons of pronotal length and width, head width, and total length revealed that males and females in malathion- and diazinon-resistant strains tend to be larger than those in normal strains. This is in sharp contrast to similar comparisons with strains resistant to organo-chlorine compounds.

THE STATE OF ORGANOPHOSPHATE RESISTANCE IN *BOOPHILUS DECOLORATUS* IN SOUTH AFRICA

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The level of resistance to a variety of organophosphate insecticides was determined using the larvae of the blue tick, *Boophilus decoloratus* Koch from the Eastern Cape Province of South Africa. The LD_{50} values of tick strains from the East London area and an organophosphate sensitive strain from Lesotho are presented. The data indicate an appreciable resistance in ticks from the Eastern Cape and suggest a pattern of resistance similar to the Ridgelands strain of *B. microplus* from Australia.

Total esterase levels measured spectrographically indicate a level of activity which is lower in the resistant strain than in the sensitive strain. An electrophoretic separation of the esterases in OP resistant strains of *B. decoloratus* and the sensitive strain from Lesotho using polyacrylamide gel show a marked difference in esterases both qualitatively and quantitatively.

MULTIPLE ALLELISM, BRAIN CHOLINESTERASES AND RESISTANCE TO ORGANOPHOSPHORUS ACARICIDES IN THE CATTLE TICK *BOOPHILUS MICROPLUS*

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The inter-relationship of genetic control of resistance to organophosphorus acaricides and of brain acetylcholinesterase (AChE) activity was investigated in five distinct strains of *Boophilus microplus* in which inhibitor-insensitive AChE and/or detoxication were the resistance mechanisms. Toxicological, histochemical and biochemical examination of F_1, F_2 and test cross progeny indicated a simple mendelian form of inheritance of resistance and of brain AChE activity in all strains. Single incompletely dominant genes or tight clusters of genes appeared to be involved in all strains which had a single biochemical resistance mechanism while two genes may be involved when there were two mechanisms in a single strain. Some of these alleles may form a multiple allelic series.

SEPARATION AND CHARACTERISATION OF MULTIPLE FORMS OF ACETYLCHOLINESTERASE FROM ORGANOPHOSPHORUS RESISTANT AND SUSCEPTIBLE STRAINS OF THE CATTLE TICK *BOOPHILUS MICROPLUS* (ACARINA)

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Five forms of the enzyme acetylcholinesterase (EC3.1.1.7, AChE) were demonstrated by electrophoresis of the soluble extract from homogenised larvae of the organophosphorus resistant Biarra and susceptible Yeerongpilly strains of the cattle tick. Earlier work established that the insensitivity to an organophosphate inhibitor and associated lower activity of the enzyme, in the resistant strain, were maintained when AChE from subcellular fractions was compared with enzyme from the original homogenate. Two of the enzyme forms, separated preparatively by column chromatography, exhibit similar total enzyme activity and sensitivity to the inhibitor in both strains and they represent the susceptible AChE component. The enzyme forms constituting the insensitive portion of AChE, that was isolated in both strains, are being further separated using preparative electrophoresis and affinity chromatography. Synthesis of substrate and inhibitor analogues is being carried out to determine suitable chemical structures on which to base acaricides for the control of the resistant strain.

SELECTION ADVANCE WITH DIAZINON IN ORGANOPHOSPHORUS RESISTANT STRAINS OF *LUCILIA CUPRINA* (WIED.)

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Organophosphorus (OP) resistance first developed in *Lucilia cuprina,* Australian sheep blowfly, which mainly initiates flystrike of sheep in this country, in late 1965. This resistance, which is non-specific and involves a range of OP insecticides, was originally of a low order (3-5 x normal with female flies) and increased to about 10 x normal by the following year. No success has followed a search for alternatives to diazinon, dichlofenthion, bromophos-ethyl, fenthion-ethyl, chlorfenvinphos and butacarb which are currently registered for the prevention of flystrike.

Surveys each year since 1965/66 showed that the level of OP resistance in field populations of *L. cuprina* has remained relatively static.

In early 1971, larvae of two strains, (termed Yantarra from southern N.S.W. and C.F.S., a strain formed by combining samples from seven areas in the State), were placed under pressure with diazinon. Both strains gave a rapid selection advance and appear to have reached a similar ceiling of response at some 50 x normal for early instar larvae.

This selection work indicates that a strain from one district and a combined strain from several districts contain sufficient genetic diversity to respond to laboratory selection with diazinon.

Further objectives of this programme were to form strains for a genetic analysis of OP resistance and for use in making artificial implants on sheep treated with OP chemicals.

A TECHNIQUE FOR TESTING EARLY INSTAR LARVAE OF THE AUSTRALIAN SHEEP BLOWFLY, *LUCILIA CUPRINA* (WIED.)

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Much attention has been given by WHO and FAO to the development of standard methods to detect resistance in insects. A primary requirement in this work is to have base-line data on the level of susceptibility for a susceptible strain of some economic species. This information is of value in establishing the order of resistance.

In the case of *Lucilia cuprina* insecticide activity and resistance studies have been conducted on adult flies and on feeding larvae. Test procedures involving larvae are significant in that it is that stage in the life cycle which is damaging. Methods with larvae include the saturation of wool or cotton wool with either blood serum or macerated liver containing an insecticide at a log series of concentrations. Fifty to 100 larvae about 12 hr old are placed on the wool or cotton wool in 4" x 1" glass tubes. Due to the difficulty in removing larvae from the treated wool, results from such tests are normally given as the concentration of insecticide lethal to all larvae.

An improvement to the above methods has been developed. A roll of paper is substituted for the wool. Strips of paper are treated with insecticide in ethanol and after drying are rolled lengthwise and inserted into 3" x $\frac{1}{2}$" flat bottomed glass tubes. Blood serum is now added to the paper onto which 20-40 larvae some 6 hr old are placed. Twenty-four hours after commencement of the test the paper containing the larvae is unfurled into a black bottomed crystalising dish containing water. The larvae can be readily counted and exact mortality records obtained.

This procedure has been very successful with *L. cuprina.* It should also have value against other calliphorid flies, including *Musca domestica* L.

POPULATION GENETICS OF ORGANOPHOSPHATE RESISTANCE IN THE AUSTRALIAN SHEEP BLOWFLY *(LUCILIA CUPRINA* WIED.*)*

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Population genetics is used to examine claims that high levels of resistance were preventing practical control of *Lucilia cuprina* in large areas of eastern Australia, and to predict the usefulness of organophosphates for controlling the pest in the near future.

From extensive collections made each spring and autumn since 1969, field resistance (LC_{50}) levels have been monitored and the responsible resistance genes isolated and characterized.

A locus on chromosome 4 with 2 alleles for resistance (one for 7x, and one for 4x) and another locus on chromosome 6 (conferring 7x resistance) were discovered.

In the region where field resistance was at a maximum (Moree, northern N.S.W.) all resistance alleles were found. Other areas carried only chromosome 4 resistance alleles (either or both) and in lower frequencies. Seasonal fluctuations in resistance levels, together with competition experiments in population cages, indicate that the resistance mechanisms (viz., modified cholinesterase and a detoxification system) place their carriers at a significant disadvantage when insecticide is not present.

The evidence suggests that until new resistance mechanisms evolve field resistance of *L. cuprina* to organophosphates is unlikely to exceed the Moree levels, and will probably stabilize at lower levels. Thus these insecticides are likely to remain as effective for the immediate future.

CONTROL OF HUMAN HEAD-LICE IN AREAS WHERE ORGANOCHLORINE INSECTICIDE RESISTANCE HAS DEVELOPED

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Human head-lice have become resistant to DDT, BHC and dieldrin in several cities in the United Kingdom. Research into the problem has also highlighted the fact that lousiness is more common than generally has been believed or officially reported, as about 2% of U.K. citizens are lousy, the majority being young children infested with head-lice.

Laboratory and field experiments with alternative compounds have led to new products being marketed, but control is handicapped by widespread ignorance of the biology of the parasite, even amongst local authority workers charged with their control.

It seems probable that resistance may develop in head-lice in any of the world's cities, if indeed it has not already done so. The interaction of toxicological, biological and social factors makes for difficulty both in recognizing resistant head-lice and in introducing more effective control measures.

CHARACTERISTICS OF A DDT RESISTANT STRAIN OF MICE

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A strain of white mice selected over thirty generations for DDT resistance had a higher total lipid content than non-selected mice. When Triton WR 1339 (oxyethylated tertiary octylphenol formaldehyde polymer) was included in the diet at 3% by weight both total lipid content and resistance fell but when 20 mg/kg of hydrocortisone and 5% by weight corn oil were added to the diet both the lipid content and tolerance rose slightly. This occurred in both the resistant and non-resistant strain. Females were at all times more resistant than males and had a higher lipid content. The resistant strain adapted more rapidly than non-selected mice to repeated stressing with cold. When the DDT metabolizing enzyme titre in microsomal pellets prepared from the livers of (1) the control strain, (2) the control strain after a challenge dose of DDT, (3) the resistant strain, and (4) the resistant strain after a challenge dose of DDT were compared no statistically significant differences were found.

CYTOCHROME P-450 IN INSECTS: CHARACTERIZATION AND ROLE IN INSECTICIDE RESISTANCE

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Cytochrome P-450 plays a central role in oxidative metabolism of xenobiotics in insects and mammals. Recent studies have shown increased levels of cytochrome P-450 in insecticide resistance strains of the housefly, *Musca domestica* L. We have now demonstrated that the cytochrome P-450 in resistant strains is qualitatively as well as quantitatively different. Cytochrome P-450 has been characterized by examination of the following difference spectra: Carbon monoxide; type I substrate; type II substrate; type III substrate (a new type of substrate difference spectrum obtained from both insects and mammals with methylenedioxyphenyl compounds and recently characterized in this laboratory); n-octylamine. It is probable that more than one cytochrome P-450 occurs in the housefly and that these resemble the cytochromes P-450 from normal and induced mammals. Current work centers around the correlation of P-450 types with the genetics of insecticide resistance and on the structure-function relationships involved in the formation of different types of substrate difference spectra.

SECTION NO. 11

MEDICAL AND VETERINARY ENTOMOLOGY

CONVENORS: R.H. WHARTON, M.D. MURRAY AND J.H. OLIVER

LARVAL MOSQUITO ECOLOGY IN RELATION TO MOSQUITO CONTROL

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The safe and efficient integrated control of mosquito pests and disease vectors will demand levels of suppression of target species at least equal to those nowadays attainable through the use of synthetic chemical pesticides alone. Among problems that await solution in this context are: the cultivation on artificial media (thereby opening the way to mass production) of leading candidate microbial control agents (*Coelomomyces* fungi, microsporidan protozoa, mermithid nematodes); provision of assurances that these agents will not pose threats to the health of non-target organisms including man, domestic animals, and wildlife; and the guaranteeing that integrated control methodologies embodying the environmental application of microbial pathogens to mosquito larval habitats will make full provision for the ingestion of adequate quantities of infective material by the actual pests or vectors under attack. This paper underlines the complexity of the latter topic, and urges the need for early attention to related research and relevant training programmes.

EFFECT OF TEMPERATURE ON DEVELOPMENT AND PREDATORY BEHAVIOUR OF *TOXORHYNCHITES BREVIPALPIS*

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The embryonic development of *Toxorhynchites brevipalpis* proceeded between 14°C and 32°C. Development was arrested below 14°C and above 32°C. The optimum temperature for both embryonic and larval development was 30°C. Optimum development of pupae occurred at 32°C. The predacious larvae of *T. brevipalpis* consumed a mean of 132.5 (26°C) to 205.0 (32°C) larvae of *Aedes aegypti*. By increasing the rearing temperature the predator larvae and consequently pupae were smaller. As 4th instar larvae approached pupation, they killed large numbers of the prey larvae without eating them. The killing behaviour appeared sooner and a greater number of prey larvae were killed per 24-hours when *T. brevipalpis* was reared at higher temperatures. During an entire life span, individual *T. brevipalpis* larva destroyed a mean of 154.2 (26°C) to 358.0 (32°C) larvae of *A. aegypti*.

BREEDING OF *AEDES AEGYPTI* AND *A. SIMPSONI* IN SHELLS OF THE GIANT AFRICAN SNAIL *ACHATINA FULICA* IN EAST AFRICA

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The giant African snail, *Achatina fulica,* is common in East Africa and widely dispersed throughout many islands in the Indian and Pacific Oceans. The mosquitoes *Aedes aegypti* and *Aedes simpsoni,* vectors of yellow fever and dengue viruses, were found developing in empty *Achatina* shells in Tanzania during the rainy season. The average density of shells in the coastal zone of Tanzania was estimated as 228 per hectare. From 11%-35% of shells were positive for mosquito larvae. *A. aegypti* was found in 82%-84% and *A. simpsoni* in 8%-13% of the shells positive for mosquito larvae. The larval density of *A. aegypti* in shells was estimated at 1,100 and *A. simpsoni* at 60 larvae per hectare during the three month period of rain. Four per cent of the shells contained viable eggs of *A. aegypti* at the end of the dry season.

INFLUENCE OF LARVAL COLOR ON THE FEEDING HABITS OF TWO MAJOR PREDATORS OF MOSQUITO LARVAE

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The feeding habit of *Culex (Lutzia) raptor*, a major predator on mosquito larvae is discussed in detail. *Lutzia* feed preferentially on the larvae of *Aedes aegypti*, *Anopheles stephensi* and *Culex fatigans* in this order. The factors which are probably involved in such selective feeding are discussed. When pale yellow or golden mutants of different species are offered to *Lutzia* these are accepted in preference to those of normal coloration. *Gambusia affinis*, another major predator on mosquito larvae, also exhibits preferential predation. These findings have direct implications in control measures, since a laboratory marker strain introduced in field experiments would be in danger of being preferentially predated. It is suggested that darker coloration has a selective advantage over the pale coloration of larvae of different prey species in field populations.

ANOPHELES FARAUTI LAVERAN (DIPTERA: CULICIDAE) IN THE OUTDOOR-BITING SITUATION

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Two types of outdoor-biting situation are described for the facultatively exophagous species *Anopheles farauti*. Both resembled natural situations and were located on the site of the developing town of Arawa (Bougainville Island, Papua New Guinea), about two miles apart and separated by two water-courses. Area 1 (uncleared) consisted of two shallow swampy tracts resulting from blocked natural drainage; area 2 included numerous small shallow breeding-places caused by bulldozer activity in clearing building sites, some still raw, others in the process of being absorbed into the landscape. In both areas night shift-work was carried out and there was much foot traffic along the roads. Reconnaissance methods included larval surveys, leg-biting catches and the use of the light trap and truck trap. Although the adult numbers taken were small relative to the larval prevalence, observations indicated stable populations of normal age-composition and expected behaviour patterns. Factors determining rises in biting densities and sampling problems are discussed. The outdoor-biting situation as a separate entity maintained by night-time activity quite remote from dwellings, of obvious epidemiological importance in the maintenance of residual anopheline reservoirs and in the transmission of disease, has not previously been investigated for this species.

CHANGES IN COMPOSITION OF MOSQUITO POPULATION IN RELATION TO NOCTURNAL ILLUMINATION

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Truck-trap collections of mosquitoes show a higher level of flight activity when the moon is shining than when it is absent. Full moon collections ranged from 11 times greater than new moon collections for *Psorophora confinnis* down to 3 times greater for *Culex nigripalpus*. The moonlit half of quarter moon nights showed 2 to 3 times more flight activity than the dark half. Gravid females of some species were more responsive to the higher illumination at twilight and during moonlit periods of the night than the population as a whole. Although blood engorged females were taken in greater proportions in crepuscular periods than during the night, a direct response

with moonlight was not clearly demonstrated. A comparison of *C. nigripalpus* collections made by various methods with vehicle aspirator collections showed all methods underestimated the proportion engorged but the amount of error was least for the truck trap.

A MOSQUITO TEST SYSTEM FOR SCREENING ANTIFILARIAL COMPOUNDS

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The development of a mosquito test system to detect antifilarial efficacy is described. In this test system, candidate antifilarial compounds are fed to yellow-fever mosquitoes, *Aedes aegypti* (L.), REFM strain, infected with the canine heartworm, *Dirofilaria immitis* (Leidy). Dissections are performed on the treated, infected mosquitoes after a predetermined period. Antifilarial efficacy, particularly causal prophylactic activity, is determined by the presence of inhibited or abnormal development patterns of the filariid parasite in the mosquito. The rationale upon which the system is based is discussed. Results of evaluation of some of the more commonly used antifilarial agents are presented.

OBSERVATIONS ON *CULEX THALASSIUS* IN ACCRA AND TEMA, GHANA

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The biology of *Culex (Culex) thalassius* (Theobald) was studied in Accra and Tema from 1964 to 1966. Although larval and adult mosquito numbers were correlated with rainfall, breeding continued in the dry season in permanent lagoons, earth drains and large bodies of water formed as a result of constructional projects.

Larvae were found breeding in a wide variety of breeding places including concrete and earth drains, stagnant streams, rainpools, swamps and in Tema also in borrow pits. Although previously not recorded as breeding in domestic compounds, appreciable numbers of larvae were found in artificial containers associated with houses.

The effect of rainfall was variable - a torrential downpour lasting a few hours washed larvae to the sea via lagoons and drains whereas light but continuous rain increased the number and size of suitable breeding places.

Only a few adults of *C. thalassius* were collected in Accra, all in a single month, but many adults were collected in Tema. Differences in adult densities in the two localities were not due to control of breeding but rather to differences in behaviour in the two localities. In Tema the adults were markedly endophilic while in Accra they were markedly exophilic. No filarial worms were found in *Culex thalassius* females even though filarial worms were found in an appreciable proportion of the adults of some of the common mosquito species collected simultaneously in Accra and Tema.

THE GROWTH OF ARBOVIRUSES IN CONTINUOUS MOSQUITO CELL LINES

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The growth of a number of arboviruses (SFV, Ross River and Kunjin) has been studied in cultured *Aedes aegypti* and *A. albopictus* cells. The effect of temperature and multiplicity of infection on virus adsorption, on latent period and on single-cycle kinetics will be described. At 28°C growth kinetics in insect cells and virus yield per infected cell are similar to that seen in infected vertebrate cells at 37°C. In mosquito cells a sharp fall in percentage infected cells occurs at 24-48 hr after infection. This is accompanied by a fall in cell-associated and extra-cellular virus titres, but not by any decrease in the rate of cell division or any increase in trypan blue staining. Electron microscopic studies show that in mosquito cells, virus matures at the external membrane and also inside large membrane-bound, electron-dense cytoplasmic structures. These structures become vacuolated and electron-lucent, apparently losing virus, at later stages of infection.

AUTOGENY IN *ORNITHODOROS THOLOZANI* (ARGASIDAE: ACARINA)

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Autogeny was first and mainly investigated in mosquitoes; in ticks oviposition by unfed females has been only occasionally mentioned. We have observed the phenomenon in *Ornithodoros tholozani* and carried out experiments in autogeny on recently ecdysed females from our regular stock. Results showed three groups (a) heavy - all autogenic, (b) medium - part autogenic, and (c) small - anautogenic. The number of eggs showed a positive correlation with the weight of females at ecdysis.

It has also been found that autogenic females not only oviposit without a blood meal, but that the eggs in the autogenic oviposition mature quicker than those deposited non-autogenically. It could, therefore, be assumed that at ecdysis, ovocytes were already in a more advanced stage of development in autogenous than in anautogenous females.

Investigation in mosquitoes has shown that autogeny has a genetic basis and that it is strongly influenced by the amount of food available in the larval culture. Whether these traits prove to be equally relevant to ticks would be a subject for further investigation.

ASSEMBLING IN *ARGAS PERSICUS*

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Both male and female *Argas persicus* produce materials which lead to assembling within and between sexes. Assay of the assembling behavior is carried out in a dish marked off in 8 sections each containing a disc of paper. Seven discs are untreated and the eighth contains the test material. When male ticks are placed in the center of the dish they aggregate in less than an hour under a test paper previously contacted by either males or females. Females also respond but more slowly.

ADAPTATIONS OF THE ARGASID TICK, *ORNITHODOROS GURNEYI*, TO THE BEHAVIOR OF ITS HOST *MEGALEIA RUFA*, A SCARCE DESERT DWELLING KANGAROO

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The argasid kangaroo tick *Ornithodorus gurneyi* is a parasite of the red kangaroo, *Megaleia rufa*, which feeds by night and rests by day. During winter days the kangaroos lie in open scrub whereas during summer they pass the day lying in "wallows" (sandy hip-hollows) under shady trees. On average, each wallow is visited only two or three times during the hot season. The kangaroo tick spends most of its life buried in the sand of these wallows and so the host-parasite interaction is centred about the wallow.

Observations on the relative susceptibility to desiccation of different stages showed that eggs and larvae died after exposure for several days to conditions which nymphs and adults would tolerate for months. Most eggs are laid in spring and early summer. In mid-summer - a time of great risk to the vulnerable eggs and larvae - high temperatures induce a reproductive diapause.

The probability that some progeny of some females will find the 5-7 meals needed to reach maturity is a function of the oviposition behavior of the female, the ability of the tick to survive protracted periods without feeding, the frequency with which kangaroos visit wallows and the ability of the tick to locate the host in a wallow.

EFFECTS OF ECDYSONES ON TICKS, ESPECIALLY ON *ORNITHODOROS MOUBATA* (ACARINA: ARGASIDAE)

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Ecdysones, the growth and moulting hormones of insects, are known to be reactive to some members of the major arthropod classes. Such information, however is completely lacking on Acarina. Ponasterone A, β-ecdysone, and inokosterone were applied to *Boophilus microplus*, *Haemaphysalis longicornis*, *Argas japonicus* and African *Ornithodoros moubata* by means of topical application, dipping, injection, continuous contact, and/or artificial feeding. Treatment with rather large doses of ecdysones, induced no noticeable changes in the moulting or in the oviposition of engorged ticks of the first three species mentioned above.

The three ecdysones manifested oviposition-inhibitory, super-moulting, and killing effects on engorged adults of *O. moubata* at doses ranging from 0.5 to 10 μg per ml of blood ingested through an artificial membrane. They also caused moulting in non-moulting nymphs fed an insufficient amount of blood or non-blood meal.

BEHAVIOUR OF CATTLE-TICK LARVAE *(BOOPHILUS MICROPLUS)* IN RELATION TO HOST RESISTANCE AND TO SITE OF PREDILECTION FOR FEEDING

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After exposure to the tick *Boophilus microplus* some British breed cattle become highly resistant. It has been shown that the greatest loss of ticks on these animals occurs within 24 hours of infestation. By using phosphorus-32 labelled ticks it was found that larvae free to wander over the host made shorter and more frequent attachments on animals of high resistance.

The distribution of larvae on the cattle was determined partly by the host's grooming and partly by selection of certain areas by the larvae. These observations are discussed in relation to feeding and to the mechanism of resistance.

SOME FEATURES OF THE DEVELOPMENTAL CYCLE OF THE TICK *IXODES RICINUS* (L.) (ACARINA: IXODIDAE)

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The developmental cycle of *Ixodes ricinus* was studied in three neighbouring microhabitats of South Moravia, thermophilic oak forest, its edge and the open meadow. A total of 30,586 engorged larvae were used in the experiment, from which 9,424 unfed nymphs and 2,382 adults developed.

In the locality studied, the length of the developmental cycle varied between 24 and 38 months, if considered as the period from unfed adult to unfed adult of the next generation, and between 15 and 29 months, if regarded as the period from the dropping off of engorged females to unfed adults of the next generation.

The length of developmental cycle is defined not only by macroclimatic and biotic, but microclimatic factors as well. While in the meadow the number of nymphs with facultative two-year developmental cycle reached 54.1% of all specimens moulted during the year from larvae which had engorged at the end of August of the past year, it reached only 3.6% at the forest edge and 0.15% inside the forest.

Similarly, the duration of the pre-oviposition period, developmental period of eggs and pre-hatch period were influenced by the microclimate. The mean pre-hatch periods in the meadow, forest edge and inside the forest were 68.5, 78.8 and 87.2 days, respectively.

IMMUNITY TO TICKS: CUTANEOUS BASOPHIL REACTIONS IN IMMUNE GUINEA PIGS

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It was confirmed that guinea pigs acquire significant resistance to the feeding of larval ixodid ticks. Hosts were infested with 100 larvae of *Dermacentor andersoni* confined in a capsule attached to the skin. The numbers of larvae engorged after seven days were recorded. Hosts were subjected to a series of such infestations, but no skin site was used more than once. Numbers of larvae, engorging during primary infestations were compared with numbers of larvae from the same batch, engorging during their host's secondary or subsequent infestations. A highly significant reduction was found in numbers of larvae engorging during secondary infestations. This was prevented by administration of an immunosuppressive drug to the hosts. Sections of infested skin from immune hosts revealed marked infiltration of the dermis and hyperplastic epidermis with basophil leucocytes. These cells were particularly numerous in epidermal vesicles which developed immediately below the mouthparts of attached ticks.

STUDIES ON THE COMPOSITION OF LONE STAR TICK *(AMBLYOMMA AMERICANUM)* ORAL SECRETIONS

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In female lone star ticks *(Amblyomma americanum)*, initial attachment, feeding, mating, subsequent engorgement and detachment from host generally spans an average of fourteen days. During the process of feeding, relatively large volumes (*c.* 500µl/tick) of unwanted fluid are eliminated back into the host and possibly through the tick's cuticle where it evaporates on the external surface. That portion of waste material returning to host tissues undoubtedly plays an important role in host reaction to the trauma associated with lesion formation. The total composition of such fluids as well as the alterations and variation that occur in these secretions during various times of the feeding process are unknown.

Preliminary studies of physiological and biochemical nature have revealed certain aspects of oral secretion composition at different times during feeding. pH determinations have shown oral secretions to be slightly basic and disc gel electrophoresis has demonstrated as few as eight and as many as 12 proteins in the oral secretions of females after different engorgement times, some of which appear to be similar. In addition, amino acid analysis has detected at least ten non-protein amino compounds to be present.

TICKBORNE VIRUSES OF BIRDS: ECOLOGY AND ZOOGEOGRAPHY

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More than 20 arboviruses in Group B and in the Hughes, Quaranfil, Kemerovo, and Uwkuniemi Groups infect specialized shelter-seeking *Argas*, *Ornithodoros*, and *Ixodes* ticks parasitizing marine and shore birds nesting in large colonies, pigeon flocks in man-made structures, vultures in large, permanent arboreal nests, and swallows in mud nests. These birds, except domestic pigeons, inhabit tick-infested sites for only a few months annually. Virus circulation factors are large densities of susceptible nestlings and ticks, accelerated tick life cycle, long survival of virus and of ticks, transstadial virus passage from immature to adult ticks, and assured availability and immediate proximity of bird hosts. Several tick species may be infected by a single virus, but species closely related to the chief vector may be inefficient vectors. Certain viruses occur widely in subarctic, temperate, or tropical belts; others are apparently more localized. Numerous different viruses infect ixodid ticks parasitizing both birds and mammals; epidemiological and ecological patterns are more complicated among these groups.

ETHOLOGICAL ASPECTS OF THE RESPONSES OF MOSQUITOES AND FLIES TO VISUAL STIMULI

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The responses of flies and mosquitoes to various shades and hues and their entrance into dark or illuminated spaces are reviewed, followed by a discussion of the environmental stimuli and the condition of the flies which might explain the great discrepancies observed between the attraction towards coloured lights and the attraction towards pigmented surfaces, as well as the contrary selection of such surfaces, on the one hand in closed rooms and on the other hand in the open air. The presumed usefulness of the attraction of insects by visual stimuli is considered in relation to trapping and control operations.

RELATIVE IMPORTANCE OF FACTORS WHICH MIGHT INFLUENCE THE BITING RATE OF *CULICOIDES* (DIPTERA: CERATOPOGONIDAE)

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The effects of ten different factors on the biting rates of three homophilic species of Ceratopogonidae *(Culicoides furens, C. barbosai* and *Leptoconops becquaerti)* have been compared quantitatively. The factors evaluated were: collector, limb, site position, lunar cycle, month of year, wind, temperature, intensity of illumination, saturation deficit and time after dawn. The most important factors were month of year and wind speed; of lesser importance were lunar cycle, temperature, collector and limb exposed; while site position, intensity of illumination, time after dawn, and saturation deficit were of minor or no importance. The three species differed in the degree to which their biting rates were influenced by these factors with *C. furens* being the most sensitive, *L. becquaerti* least and *C. barbosai* intermediate.

A COMPARISON OF THREE SPECIAL TRAPPING METHODS TO INVESTIGATE DAILY AND SEASONAL ACTIVITY OF *CULICOIDES* (DIPTERA: CERATOPOGONIDAE)

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Three special trapping methods were compared in an investigation of the daily and seasonal activity of *Culicoides* species in Southwestern Virginia. These were (1) a specially designed animal trap; (2) a modified New Jersey black-light trap and (3) a portable motorized insect vacuum sweeper. Graphs are presented showing the seasonal distribution of 11 species, and preliminary data are given for 8 other species. Daily activity for 10 species is also presented. The black-light trap collected the largest numbers of most species. The animal-baited trap was selective for certain species, particularly *Culicoides sanquisuga* (Coquillett). The vacuum sweeper was the least selective and collected more species than the other traps.

STUDIES ON THE VERTICAL STRATIFICATION OF FLYING *CULICOIDES FURENS* (POEY) (DIPTERA: CERATOPOGONIDAE)

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Although it is generally accepted that apetential flight in *Culicoides* occurs near the ground, poor control with thermal fogging suggested a higher flight level. Therefore studies were initiated using a 45 ft tower.

Trapping was at 2 ft, 6 ft, and every five foot interval from 10 to 45 ft using either greased "Rotorod" (Metronics Inc.) samplers or greased plastic cones over small light bulbs. Average nightly wind speed was determined at 6, 20 and 40 ft.

Along the edges of mangroves and dense beach ridge vegetation (sea grape and sea almond) maximum sandfly recoveries were at 20-25 ft, corresponding to the stratum of dense canopy and, usually, lowest wind velocities. In an open grassland locality at wind speeds below 3 m.p.h. maximum recoveries were still up at the 10-25 ft level.

ASPECTS OF TRAPPING PHLEBOTOMIDAE AND SIMULIIDAE (DIPTERA)

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Collecting sandflies and blackflies on human bait is a common practice but provides limited information. Resting habits determine some methods of collecting sandflies but it is important, and difficult, to find resting gorged females. The flight habits of sandflies have led to the development of sticky-paper traps in open country and rodent-baited oil traps in forest. It is difficult to assess parous rates of sandflies accurately, but possible to use approximate methods for studying general trends. Nulliparous and parous blackflies tend to behave differently. Methods of finding resting blackflies are needed in studying host preference, relation to disease, and dry-season survival. The parous rate in blackflies captured in West African forest is relatively low, and it is difficult to interpret the results in relation to transmission and incidence of onchocerciasis. Blackfly larvae move their position and are taken on artificial resting sites.

COLLECTION OF AUSTRALIAN *PHLEBOTOMUS* FOR VIRUS TESTING

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and H.A. Standfast

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Phlebotomus in Australia are generally abundant where the annual rainfall is less than 25 in. and also in the higher rainfall zone of the north wherever there is an extended dry season. Local distribution is often patchy and may reflect a close association with reptiles. Methods used for collecting sandflies in arbovirus surveys have been influenced by these factors of distribution and abundance coupled with limited available knowledge on host preferences and the overriding requirement of live females of suitable physiological age.

Man and livestock were rarely attacked and traps baited with rodents or reptiles have not yet proved productive. Egress traps set overnight have caught up to 51 sandflies from a single reptile burrow, but males predominated with few females suitable for virus testing. However this method and animal baiting has contributed useful biological data. Only small catches were made from other natural resting places including hollow trees, mammal burrows and ground cavities.

Catches of several hundred suitable females per night were taken in a battery operated light trap fitted with screens to exclude larger insects and minimise damage to the sandflies. The truck trap returned smaller but useful collections for the virologists as well as providing data on flight patterns.

USE OF TRAPS FOR SURVEY AND CONTROL OF TABANIDAE: DIPTERA ON THE NEW JERSEY SALT MARSH

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Box (Manning) traps are easy to construct and maintain and catch up to 10,000 *Tabanus* per day. Partial control of flies can be achieved in limited areas. Experiments are in progress to determine actual *Tabanus* populations on a marsh by using a mark-release-and recapture technique. Marked flies have been recaptured for nine days after release and up to 1.0 km from the release point. Canopy (Manitoba) traps with a black decoy, also effectively measure distribution and seasonal abundance of *Tabanus*. As a decoy a black skirt at the bottom of the canopy is superior to a black sphere hung beneath the trap. Carbon dioxide evolved from dry ice in the trap increases the number and variety of Tabanidae captured. Vertical sticky panels set on stakes capture both *Tabanus* and *Chrysops*. Dark colored traps are best and increasing the trap height above the marsh increases the number of *Chrysops* captured.

CARBON DIOXIDE TRAPS AS A TOOL FOR MEASURING DISTRIBUTION AND ABUNDANCE OF VARIOUS TICK SPECIES

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An effective and economical tick trap for dispensing CO_2 under woodlot conditions was developed and used to demonstrate that all developmental stages of the lone star tick, *Amblyomma americanum* (L.), are attracted to CO_2. The average number of ticks per sample from trap catches was many times greater than the number collected per sample through flagging methods, and less variability occurred among CO_2 trap samples. Behavioral responses of adult and nymphal lone star ticks to CO_2 were not noted at temperatures below 10°C. During cool weather the highest number of ticks was drawn to the trap approximately 3.5 hr after the maximum daily temperature was reached. Ticks marked with fluorescent dyes were attracted from as far away as 21.3 m, and the effective sampling area of the trap was approximately 25 m^2. Lone star nymphs and adults were collected more abundantly with the aid of CO_2 where heavy overstory, light understory and thick soil duff or litter occurred. Carbon dioxide traps appeared to minimize sample variation that generally occurred with flagging as a result of physical differences within woodlots. These and more recent studies suggest that when flagging methods are used in sampling, behavioral differences between tick stages could account for apparent relationships between stages and vegetative habitat types that do not actually exist.

Other tick species collected with CO_2 traps during these investigations include *Amblyomma maculatum* Koch, *Dermacentor albipictus* (Packard), *D. variabilis* (Say) and *Ixodes scapularis* Say.

LABORATORY STUDIES ON TRANSMISSION OF VIRUS DISEASES BY *CULICOIDES VARIIPENNIS*

R.H. Jones

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The first laboratory research with colonized *Culicoides* as vectors of a virus disease was with bluetongue and *Culicoides variipennis* (Coquillett). The multiplication curve and replicative cycle of the virus in the fly, transmission between sheep and cattle, and serial transmission of the disease from vaccinated animals were demonstrated at Denver, Colorado, U.S.A.

Transovarian transmission by *C. variipennis* was shown to be unlikely. The susceptibility rate of the parent colony to BT-262 virus was found to be about 30% in studies with repeated infective meals. Lines of flies resistant and susceptible to oral infection by bluetongue virus were developed through genetic selection. Infection rates were about 1%, 60%, and 90% for a single infective blood meal as compared with the rate of about 22% for the parent colony. The resistant line was resistant and the susceptible lines almost completely susceptible when given repeated infective blood meals.

ISOLATION OF VIRUSES FROM FIELD POPULATIONS OF *CULICOIDES*

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In recent years *Culicoides* have been associated with a substantial number of viruses isolated from wild populations in several countries. In Nigeria, 13 different viruses were isolated from the genus from 1967 through 1970. The viruses include the Simbu group (Sabo, Sango, Sathuperi, Shamonda and Shuni), a new virus of the Palyam group (Abadina), a new rhabdovirus indirectly related to rabies (Kotonkan), EHD-related virus, RVF, BRV, the tick-borne viruses (Congo and Dugbe), and an unidentified virus also obtained from passerine birds.

Important to success in the isolation of those viruses from field populations was the examination of large numbers of individuals. Because of the slight bulk of *Culicoides* and their susceptibility to rapid desiccation, techniques in handling from time of capture to viral assay require special attention to avoid inactivation of virus. Also because of their small size, the dilution factor during processing must be kept at a minimum.

Regardless of whether a biological cycle is involved or not, the sampling of wild populations of *Culicoides* for arthropod-borne viruses has proven to be of value in monitoring the activity of certain viruses in localized areas in Nigeria.

RECENT PROGRESS IN RESEARCH ON CHICKEN LEUCOCYTOZOONOSIS IN JAPAN

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Progress has been made in understanding the epizootiology of leucocytozoonosis through research into the relationship between the biting midge, the protozoon *Akiba caulleryi*, and the chicken. It has been enhanced by the success of laboratory colonization of *Culicoides arakawae*, the adoption of a much refined technique for the experimental infection of host birds with *A. caulleryi*, and a quantitative method of observation of the infection course. The predominant importance of *C. arakawae* as the main vector of leucocytozoonosis among many *Culicoides* species, and the chicken as the sole host among various gallinaceous birds was revealed by surveys of the geographical distribution and seasonal incidence of the disease. Quantitative relationships were established between the severity of symptoms, fatality in infected chickens, schizont production in relation to the number of sporozoites inoculated, age factor, and immune reactivity of chickens.

CERATOPOGONIDAE AS PESTS OF MAN IN AUSTRALIA

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Species known to attack man in the Australian Region belong to the genera *Leptoconops*, *Styloconops*, *Austroconops*, *Lasiohelea* and *Culicoides*. Of these the most important are *Culicoides* and *Styloconops*.

Culicoides presents problems mostly in estuarine areas, *Styloconops* on some sandy beach areas but not typical surfing beaches.

Areas mostly affected have not had much human population in the past but involved areas are increasingly used residentially and recreationally. The problems are important in some newly developed residential areas, industrially significant in a few cases and of considerable tourist significance.

The problems have been emphasised because of the natural processes of development in Australia, more so in some areas because of development being determined by industrial needs and occasionally development has itself created problems.

The effects on man are various, from insignificant to important but are not basically entomological in their expression. However the avoidance techniques of the past are no longer acceptable to our present population and will become less so as time goes on.

THE BIONOMICS OF ADULT CERATOPOGONIDAE - A REVIEW

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In range of feeding habits, Ceratopogonidae are a microcosm of the Diptera.

The sugar-meal, taken by the labella, is poorly known, especially in the predaceous Ceratopogoninae. The protein-meal, obtained (females only) by use of the mandibles, is usually from body fluids of vertebrates or insects, but some Forcipomyiinae feed (perhaps primitively) on pollen or carrion. The protein-meal is lost, partially or completely, in certain species and higher groups. Typically host-finding involves chemical stimuli, sometimes specific, but many Ceratopogoninae have a new system of preying on small insects in flight in their mating swarms.

Mating is typically in flight, by auditory recognition in a swarm over a visually recognised marker; but reduced processes occur and are sometimes correlated with adaptive reduction of the protein-meal. The hunting process of predaceous Ceratopogoninae probably originates from the swarm-finding process proper to mating, and in several tribes the females feed on their own males during copulation.

SYNOPSIS: A COMPARISON OF THE FLIGHT PATTERNS OF *CULICOIDES* AND OTHER BLOOD-SUCKING NEMATOCERA

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A truck trap was used to determine the patterns of flight activity of blood-sucking Ceratopogonidae, Culicidae, Simuliidae and Psychodidae. The aggregate flight of *Culicoides* females commenced late in the afternoon and rose sharply to a brief major peak just after sunset; activity fell off rapidly at first, continued through the night with some fluctuations but gradually fell to a very low level at dawn. A short term secondary presunrise peak was followed by very low flight activity until noon when flight ceased. The combined flight of males followed the same pattern as for females.

There were some differences in the patterns of the flight of females of the four dominant *Culicoides* species. For example *C. austropalpalis* contributed proportionally less to the crepuscular activity but dominated night time collections. There is evidence that different age sectors of a species exhibit different patterns of flight activity. Empty nullipars of *C. marksi* commenced to fly earlier in the afternoon than did the empty parous females.

An increased flight of *Lasiohelea* females began soon after noon, rose gradually until dusk when it dropped sharply to a low level and ceased before midnight. It was resumed again after dawn and a short term but dramatic peak coincided with the morning peak of *Culicoides* flight. Flight continued at a low level during the forenoon.

Female Culicidae became active during late dusk at the time when *Culicoides* flight was subsiding. Flight activity rose sharply and was sustained until about midnight after which it fell gradually to cease before sunrise. There was no appreciable dawn peak and the flight of females was strictly nocturnal. *Phlebotomus* were taken in small numbers. Their flight pattern appeared to follow that of Culicidae. The flight of Simuliidae was diurnal with pronounced pre-sunset and post-sunrise peaks of activity.

ENVIRONMENTAL ADAPTATIONS OF IMMATURE CERATOPOGONIDAE

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Any study of the life of immature ceratopogonids is rendered difficult by the small size and usually secretive habits of the subject material. Direct methods of observation are for the most part impossible, at least under field conditions, and consequent reliance upon indirect methods is at once both time-consuming and fraught with the possibility of interpretive error. The present discussion reviews some of the work, which, in spite of these difficulties, has and is being done to improve our knowledge of the environmental adaptations and requirements of ceratopogonid larvae and pupae. Ignorance of these details has, as much as any other single factor, held the development of laboratory culture techniques and dependent disciplines to their present inadequate level.

THE CREATION OF ARTIFICIAL ENVIRONMENTS FOR LABORATORY REARING OF *CULICOIDES* LARVAE

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The creation of a suitable artificial environment for the immature stages is a major problem in the development of suitable rearing techniques of species of *Culicoides*. Factors such as temperature, diet (natural or artificial), and larval density are evaluated in experiments using a 6-year-old laboratory colony of *C. guttipennis* (Coquillett). Techniques developed by other workers in the propagation of *Culicoides* are outlined and compared with techniques developed in the rearing of other Nematocera, particularly Culicidae.

LABORATORY COLONIZATION OF BITING MIDGES (FAM. CERATOPOGONIDAE)

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Two *Culicoides* and one *Forcipomyia* midges have been colonized in the laboratory and completed 6-7, 5-6 and 10-11 generations respectively. Adult midges were kept in rearing cages made of 2 rounded plastic plates and 3 copper rods covered with white nylon stocking material. A small bulb containing 5% glucose solution is set in the upper plate of the cage to supply sugar requirements. Rearing cages are placed in a flat dish with several layers of moistened filter paper and blood provided by exposure to a newborn mouse. Eggs are deposited 4-5 days after feeding and hatching occurs 2-3 days after oviposition. The medium for *Culicoides* larvae which are aquatic consists of water and yeast-blood-agar-base cake while the medium for

Forcipomyia larvae which are terrestrial consists of laterite clay and yeast powder. The life cycle from egg to adult for *Culicoides arakawae* was found to be 26(24-28) days, for *C. schultzei* 30(28-32), and for *Forcipomyia taiwana* 24(21-26) days.

INSECT GAMETOGENESIS

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In higher insects both the male and female gametocytes undergo cycles of mitosis accompanied by incomplete cytokinesis. This results in clusters of sister cells joined to one another by systems of canals. The final number of joined "cystocytes" is constant for a given species and sex. Subsequently all male cystocytes, but only one female cystocyte in a cluster completes meiosis. The remaining female cystocytes grow and transfer their cytoplasm through the canal system to the oocyte. Endomitosis in these "nurse cells" serves to multiply the cistrons that transcribe the RNA components of the ribosomes which are stored in the ooplasm in vast numbers. In the nuclei of oocytes and spermatocytes only one chromosomal replication cycle takes place, and this is generally followed by the assembly of synaptonemal complexes. Studies of aberrant forms of gametogenesis in insects possessing mutant genes that markedly influence their fertility provide insights into the genetic control of these phenomena.

MEETING OF THE SEXES

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As parasites, the sexes of many species meet and mate in the burrow, lair or rookery of the host or on or near free-roaming hosts which they have sought out. Another common method of encounter is meeting at a specific site attractive to both sexes (e.g., a hilltop, stream or trail). Males of such species swarm or hover over a specific marker or distinctively perch on some landmark. Males wait for females at aggregation sites for about 30 minutes to several hours each day; females generally are present at such sites only as long as it takes to copulate. Pursuit by a male and subsequent coupling occurs after a female enters a male swarm or flies over a perched male. Females may be accepted or rejected, within centimeters, on the basis of chemical, acoustic, visual or tactile stimuli. Sex pheromones do not appear to attract from long distances.

SPERM TRANSFER IN INSECTS OF MEDICAL AND VETERINARY IMPORTANCE

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Methods of sperm transfer in parasitic insects will be reviewed. The significance of many of the methods of sperm transfer can only be fully understood in relation to the selective pressures that have led to their evolution. This is particularly true when we come to consider the broader aspects of haemocoelic insemination. In recent years entirely incompatible opinions have been expressed about the significance of haemocoelic insemination in bedbugs. Some claim that the selective value of this method of insemination can only be fully understood if it is also considered as a method of supplying the inseminated individual with food. The little experimental evidence now available is, however, against such a view. The relevance of this type of evidence will be discussed in relation to certain bedbugs that appear to be the only animals that have organs especially evolved to facilitate homosexual copulation.

REPRODUCTION IN MITES AND TICKS

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Production of spermatids in *Ixodes* (Prostriata) and argasids first occurs after feeding during the last nymphal stage. Adults must feed before spermatids are produced by most Metastriata. Spermatids in all ticks fail to complete maturation unless transferred to females. Little information exists on timing and development of spermatids in other acarines. Female acarines generally must feed before eggs develop. Most female Metastriata must partially feed before males mate with them and mating is necessary for females to complete feeding.

Pheromones are produced by both sexes of some Ixodidae and serve to bring the sexes together. Certain mesostigmatid and prostigmatid mites also produce sex attractants. Many acarine species produce spermatophores which are inserted into the female genital opening or into Michael's sperm induction pore. Morphology and development of spermatophores are discussed. Spermatid relocation and the role of genital accessory glands in reproduction is evaluated, as are relationships between feeding and oviposition.

REPRODUCTION IN MOSQUITOES AND OTHER DIPTERA

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Reproduction in dipterans of medical importance will be discussed with emphasis on development of the ovarian follicle, ovulation, fertilization, and maturation of the oocyte. Spermatogenesis will be discussed and the effect of mating on the behavior of the female. The question of population reproduction will be considered.

REPRODUCTION IN OTHER ARTHROPODS OF MEDICAL AND VETERINARY IMPORTANCE

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The paper will focus on the reproductive biology of two medically important groups - the tsetse flies, as exemplified by *Glossina austeni*, and the triatomine bugs, represented by *Rhodnius prolixus*, with a more superficial treatment of some other groups. *Glossina* reproduces by autotrophic viviparity: all of the nutrition necessary to produce a new adult fly is transferred to the larva while it is within the uterus of the mother. The necessity for large blood meals and the ability to fly, coupled with a rapid transfer of metabolites from the blood to the larvae via the milk gland, has produced some interesting physiological problems for the fly. These problems, and some of the solutions, will be discussed. In *Rhodnius*, our attention has been directed to the way in which information about critical physiological events such as feeding or mating, is transmitted to the ovary via the endocrine system.

DEMODICIDS (ACARI: DEMODICIDAE) OF MEDICAL-VETERINARY IMPORTANCE: STATUS AND PROBLEMS

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A review will be undertaken of the described species of hair follicle mites (*Demodex* spp.) of concern to physicians and veterinarians. Information examined will include such topics as: mite species characteristics, life cycles, sites of infestation and adaptations, host tissue derangement at both the gross and histological levels, and evidence of mite-host interactions. A key to these mite species will be made available to congress participants.

Problems associated with these species such as the following will be discussed and evaluated: (1) validity of species descriptions, (2) synhospitalic species and host specificity, (3) measurements of population dynamics, (4) mite transfer and host behaviours, (5) assessment of incidence, (6) pathogenesis and disease transmission, (7) control and reduction of incidence. In assessing these problems, some attempt will be made to indicate areas of research which are in special need of attention.

STUDIES IN THE FIELD OF MEDICAL AND VETERINARY ENTOMOLOGY IN THE UKRAINE

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Scientists of the Ukrainian SSR have devoted great attention to research on medical and veterinary entomology. The species composition, biology and distribution of parasitic and blood sucking Diptera, of synanthropic flies, of fleas, biting and sucking lice are being studied intensively. In particular studies have been made on the population dynamics of blood sucking insects, the effect of environmental factors, their seasonal and daily activity and their role as vectors of pathogens. Problems of quantitative calculation and outbreak forecasting of blood sucking insects are investigated. As a result rich factual scientific information reflecting zone and landscape peculiarities in relation to the distribution and dispersal of parasitic and blood sucking insects in the territory of the Ukraine, their biotic interrelations and their dependence upon natural and social factors have accumulated.

The persistent activity of entomoparasitologists of the Ukraine together with the workers of the medical and veterinary services has led to the sharp limitation of transmissible diseases and even to complete elimination of some of them. Malaria, pappataci fever and spotted fever have been eliminated while the incidence of some other arthropod-borne diseases of man and domestic animals has been reduced. Every effort is made to use the complex of biological and chemical control methods closely connected with hydromeliorative, agrotechnical and organization-economical measures.

SURVEY OF INJURIES TO MAN BY AUSTRALIAN TERRESTRIAL ARTHROPODS

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The paper surveys the injurious effects to man of terrestrial arthropods in the Australian region, initially according to a classification of mechanisms of injury:

1. Contact irritations from chemical secretion, exudate or spray e.g. *Mictis* (Hemiptera), vesicant beetles, millipedes such as *Polyconoceras*.
2. Effect of bites, skin puncture and injection of salivary secretion, e.g. mosquitoes, bedbugs, ticks, mites, thrips, centipedes, spiders. Only in *Ixodes* (Acarina) and two species of spiders *(Atrax* and *Latrodectus)* is the secretion potentially lethal.
3. Injection of venom from non-salivary single gland, e.g. Hymenoptera, scorpions. Venom likely to be physiologically active.
4. Effects of spines and bristles without venom gland, e.g. insect spines, including caterpillar ophthalmia.
5. Effects of spines and bristles with a venom gland, e.g. stinging caterpillars.
6. Sensitization effects upon skin or respiratory membranes from allergenic substances, e.g. hymenopteran venom, or inhaled lepidopteran scales or insect fragments.

Examples of each of these categories (which tend to overlap) are given. A systematic survey follows, with an overall assessment of significance.

A PRELIMINARY STUDY ON SHAPE DISCRIMINATION IN HOUSE FLIES

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Plastic trays containing white filter paper with 5 black squares (2 x 2 cm), circles (2 cm diam.), triangles ($2\frac{1}{2}$ x 2 cm) respectively, arranged X-wise, and a white blank were placed in 12 *Musca domestica* breeding cages from hatching, with each batch's food always in the same tray. At 5 to 15 days, batches were starved for 24 hr, then placed in a 60 x 60 x 90 cm mesh cage containing identical trays with water fitted over holes in the floor with a Kodak cold-light illuminator underneath. Two 'unexposed' batches were also tested.

In 14 tests totalling 3000 flies, squares gave a mean preference of 30.6%, circles 28.4%, triangles 21.0% and blanks 19.9%, each with 1.5% S.E. There was no significant difference in preference between the various batches. It is suggested that *M. domestica* does not discriminate between circular and square shapes, but prefers either to a triangle or a white blank. The possibility exists that conditioning could be masked by other responses.

THE ASSESSMENT OF THE FAVOURABILITY OF HABITATS FOR THE TICK *BOOPHILUS MICROPLUS* IN AUSTRALIA

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The physical environment plays a dominant role in determining the fate of non-parasitic stages of *Boophilus microplus*. The eggs and larvae are more susceptible to disiccation than are the fed females, but all stages may be exposed to lethal temperatures. This differential susceptibility of the different stages has to be taken into account when developing quantitative indices of favourability for different habitats and in different seasons. A complex of factors is involved, particularly pasture cover and near-surface soil moisture. An account will be given of attempts to find indicators of the microclimate in pastures from standard meteorological data.

LABORATORY EVALUATION OF TICK REPELLENTS

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A total of 688 chemicals were evaluated in the laboratory against the local tick *Ornithodorus tholozani* Labou. and Mégn. The shaved bellies of rats were treated with 100% of the repellents (or 50% in ethanol) and the number of ticks feeding after various periods of time after treatment was determined. The best chemicals were divided in groups of about six, including a standard (dibutyl butane phosphonate) and tested in round robin series. Pyrethrum extract at 0.25% in ethanol was far superior to all the other chemicals. *N-alkyl*(C_{12}-C_{14}) cyclohexylamine and 2-dicyclohexylaminoethanol were highly significantly superior to the standard. The following chemicals were not significantly different from the standard: lactic acid ester with phenyllactate acetate; 1,1,3,3-dipentamethyleneurea; *alpha*-tert-butylpiperonol; l-(p-chlorophenyl)-3-methyl-2-butanol; *M,M*,-*o*-triethylbenzamide; *p*-bromophenyl dichloroacetate; 2,4-hexadienyl *o*-ethoxy benzoate; propylene trichloroacetate; 2-(2-butenyl)-4-methoxyphenel; dipentyl malate; diisopentyl malate.

SAMPLING OF POPULATIONS OF THE LONE STAR TICK, *AMBLYOMMA AMERICANUM* (L.) (ACARINA: IXODIDAE) WITH CO_2-BAITED TRAPS

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When blocks of dry ice were used as a source of carbon dioxide to bait traps for the lone star tick, *Amblyomma americanum* (L.), a 3-host species, the number of adult ticks was found to peak from March to June; nymphs were most abundant in September and October. The trapping devices were flannel cloths laid on the ground, with the dry ice above them on inverted hardware cloth baskets. The pastures studied at the Kerr Wildlife Management Area, Kerr County, Texas, were either unstocked, stocked with exotic deer *(Axis axis* and *Cervus nippon)*, or stocked with combinations of cattle, sheep and native white-tailed deer *(Odocoileus virginianus)*. Smallest numbers of ticks were collected in a pasture stocked with exotic deer; while the largest numbers were collected in a pasture stocked with cattle and native white-tailed deer.

EFFECTIVENESS OF USING REPELLENTS AGAINST ARTHROPOD VECTORS OF INFECTIONS

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Methods of individual protection in the foci of natural infections of transmissible character are of major significance in the complex of prophylactic measures. The level of susceptibility to repellents in blood-sucking arthropods belonging to families Ixodidae, Argasidae, Culicidae, Simuliidae, Heleidae and Phlebotomidae was studied. Threshold (TD50) and repellent (RD95) dosages were used as criteria for evaluating the repellent susceptibility of ticks.

Different recommendations are required for preparations intended for use in various zones. Of not less importance is the development of rational forms and ways of using repellents. Rates of skin evaporation and absorption of various formulations of DEET, benzimin, carboxide are discussed. The use of repellents in individual focus types is determined by epidemiological evidence, the entomological problem, effectiveness of the control program and the level of susceptibility to repellents of dominant groups of blood sucking arthropods.

SPECIATION IN THE *SIMULIUM (EDWARDSELLUM) DAMNOSUM* COMPLEX (DIPTERA: SIMULIIDAE)

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The study of the giant chromosomes of populations of *S. damnosum* from throughout central Africa has shown that this species, to date, is in fact a complex of about 16 species which splits into two subgroups, Nile and Sanje, on both cytological and morphological grounds. Nile subgroup includes nine forms, six from west Africa. The seven Sanje subgroup forms are found only in east Africa along with four Nile subgroup forms. Within each subgroup morphological differentiation of forms has too often been frustrated by their apparently identical morphology, although biological differences exist. Just which of these forms bites man and is therefore capable of transmitting onchocerciasis is not yet known with certainty. Correlation of breeding sites with onchocerciasis transmission indicates most Nile subgroup forms, but only one Sanje subgroup form, may be transmitters. This chromosome study also permits a remarkably accurate tracing of phylogenetic relationships between all cytological categories.

STUDIES ON THE SPECIES OF THE *ANOPHELES PUNCTULATUS* DÖNITZ COMPLEX

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The taxonomic status of the members of the *Anopheles punctulatus* Dönitz complex, the most important vectors of malaria in New Guinea and surrounding areas, has been controversial in the past. Over 150 females of this complex were obtained from north Queensland in Australia, New Guinea and the Solomon Islands. Their progeny were identified by cross-mating experiments; interfertile populations were regarded as conspecific and populations which were not interfertile were regarded as belonging to different species. Four species were found. Using the morphological criteria of Rozeboom and Knight (1946), one of these was identified as *Anopheles punctulatus*, one as *A. koliensis* Owen and two as *A. farauti* Laveran. These latter 2 species have been provisionally designated as *A. farauti* No. 1 and *A. farauti* No. 2. *A. farauti* No. 1 was obtained from New Britain and the Solomon Islands and *A. farauti* No. 2 from Australia.

The relationship between these species, as revealed by hybridizing experiments and examination of the chromosomes will be discussed.

THE *ANOPHELES ANNULIPES* COMPLEX OF SPECIES

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Anopheles annulipes is a highly variable mosquito that is widespread over the Australian continent and some of the neighbouring islands. Previously it has not been seriously suspected of being anything other than a single species. The writer's work indicates that the current description of *Anopheles annulipes* covers at least two sibling species, the morphology of which appear to be identical from preliminary studies. The newly discovered species are characterised by (a) differences in the banding pattern of the XR chromosome in polytene complements of chromosomes from the salivary glands of fourth instar larvae, (b) a high degree of asynapsis between homologous chromosomes from the salivary glands of hybrid larvae, (c) sterile, hybrid, male adults, as evidenced by the greatly reduced size of the internal genitalia, and lack of spermiosis. The two new species have been collected as larvae from the same breeding site giving added weight to the interpretation that these forms are species in an evolutionary sense.

REPRODUCTIVE ISOLATION BETWEEN MEMBERS OF THE *CULEX PIPIENS* COMPLEX IN WESTERN AUSTRALIA (DIPTERA: CULICIDAE)

H.E. Paterson

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It is very difficult to reconcile the conflicting statements on the evolutionary status of members of the *Culex pipiens* complex which are to be found in the voluminous literature. For this reason it is important to study pertinent situations which appear to be susceptible to a population genetic approach.

In Western Australia four members of the complex coexist at many places, thus offering an opportunity to obtain significant new data. Two forms are endemic, *Culex australicus* Dobrotworsky and Drummond and *C. globocoxitus* Dobrotworsky, and two are introduced, *C. fatigans* Wiedemann and *C. molestus* Forskal. The careful sampling of natural populations has revealed few natural hybrids. This apparent reproductive isolation has been supported by experimental studies, which throw new light on the basis of the assortative mating.

These data are interpreted in terms of a genetical species concept. Attention is also paid to some currently accepted but contrary interpretations.

THE *MUSCA DOMESTICA* COMPLEX - THE PRESENT POSITION (DIPTERA)

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A feature of modern entomology is the gradual reassessment of the evolutionary status of important insects in the light of genetical concepts of the species. *Musca domestica* has caused considerable trouble in this respect, and the present contribution sets out to review what has been achieved so far in Africa and Europe and to contribute new data from a recent investigation of natural populations in Ceylon, Mauritius and Australia.

The method of approach used in this work depends on careful sampling in the normal habitat of each of the forms studied: that is in the habitat where mating normally occurs. This simple precaution avoids confusion, which arises from sampling at breeding places (more than one form may use the same breeding place), or at food baits, which may attract flies from their normal habitat. These precautions ensure that behavioural and ecological aspects of reproductive isolation are fully appreciated.

Studies so far indicate that *Musca domestica* can be subdivided into several subspecies, some of which are rather strongly reproductively isolated from each other in nature. This has enabled them to coexist for quite long periods following the secondary overlap of their ranges due to the interference of man.

BEHAVIOURAL STUDIES OF THE GENUS *MUSCA* (DIPTERA: MUSCIDAE)

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It has been demonstrated that behavioural differences exist between closely related species and that these differences can often be used to confirm and/or add to the already existing phylogenetic scheme. Behavioural studies using members of the genus *Musca* are greatly needed. Attempts are presently being made in two laboratories to correlate mating behaviour studies and studies of the defensive immune behaviour of two species, *Musca domestica* L. and *M. autumnalis* De Geer, with respect to their taxonomic positions.

In the field, face fly and house fly do come into contact. This suggests that interspecific mating attempts and/or mating may occur. Crosses in the laboratory between the two species showed that male house flies will mate with female face flies, but the opposite cross does not occur. In the successful cross, sperm is transferred and females lay eggs. Analysis of the mating behaviour reveals small differences in the courtship rituals of the two species.

House fly larvae infected in the laboratory by the nematode parasite *Heterotylenchus autumnalis* demonstrated an immune behaviour response. This response involved hemocytic encapsulation of the parasite. No such reaction is evident in the normal host, face fly. It is suggested that by utilizing this parasite and any host reactions of the larva to the parasite, one may explore the host specificity of other members of the genus and see how this fits into the present phylogenetic scheme.

These two diverse types of behaviour, mating and immune response, provide the taxonomist with additional information in looking at intrageneric relationships.

ASPECTS OF BEHAVIOUR AND ECOLOGY OF *MUSCA DOMESTICA* L. (MUSCIDAE: DIPTERA) IN NORTHERN EUROPE

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In Northern Europe *Musca domestica* populations depend on the presence of stables and sheds, where cattle, pigs or horses are kept. The stables etc. provide shelter, food and breeding media for the flies. The overwintering takes place by slow breeding in stables and sheds, mainly in calf pens. In the summer the house flies spend the night and much of the day-time indoors in stables etc., but breed to a great extent in dung-heaps outside.

Aspects of the behaviour of the house fly adapting it to this habitat are discussed, particularly the distribution of flies as influenced by temperature, light and other visual stimuli, and location of animals, food and breeding material. The night-resting and breeding habits are compared to those of *Musca domestica* in warmer climates. House flies in northern Europe do not breed in pure cow manure, but predominantly in manure of pigs, young calves and, where available, of horses.

GENETIC CHARACTERISTICS OF THE HOUSE FLY INCLUDING ANOMALOUS FACTORS

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A brief review of the general genetic characteristics of the house fly including the linkage groups, the karyotype and their relationship, chromosome maps including mutant markers, sex-determination mechanisms and cytogenetic factors including crossing over and mitotic pairing, will precede a discussion of some anomalous genetic factors. The anomalous factors include: (1) a strain of house flies that possesses male determining factors on three different autosomes, (2) all fourth chromosomal visible mutations show tight linkage (very little crossing over) or free recombination, (3) Y-autosome translocations show higher than expected fertility and production of males, (4) lack of mutant markers on the sex chromosomes, and (5) generalized positions effects and sex-limited factors which reduce the expression of a dominant mutant. A short discussion of the importance of formal genetic studies on insects of medical and agricultural importance will also be presented.

THE ADAPTIVE STRATEGIES OF THREE SPECIES OF DUNG-BREEDING *MUSCA (VETUSTISSIMA, AUTUMNALIS,* AND *SORBENS)*

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Musca vetustissima, autumnalis, and *sorbens* all lay eggs in single animal droppings, where the larvae live and feed until they migrate out of the dropping to pupate in the surrounding soil. The adults require water, carbohydrate, and protein in order to survive and breed successfully, and they frequently obtain part of these requirements from the eyes, orifices, or wounds of mammals. The pest status of these species in various parts of the world testifies to their successful exploitation of this niche and has ensured the attention of entomologists; consequently a body of data has accumulated concerning the biology, needs, and limitations of each.

From the data available it is possible to construct conceptual models of the life system of each species, although there are a number of points where the results of work done on one species strongly suggest major gaps in our knowledge of the others. Comparisons of such ecologically similar specialists may thus provide a useful framework for further enquiry.

THE BEHAVIOUR OF *GLOSSINA* (DIPTERA: GLOSSINIDAE) IN RELATION TO THE EPIDEMIOLOGY OF HUMAN SLEEPING SICKNESS

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Bursell's studies between 1959 and 1967 on the nutrition states of samples of *Glossina* caught by different techniques opened a new approach to the epidemiological roles of these insects in the trypanosomiases which has scarcely begun to be explored. Any epidemiological model for vector-borne disease must include among its principal parameters the frequency of infective bites delivered to the population at risk.

Tsetse flies of the *morsitans* group, which provide the main transmission link between wildlife hosts of human trypanosomes and transmission cycles in which man himself is intimately involved, may themselves bite man only rarely. Those flies which do bite man can generally be distinguished from others in the population by their nutrition state and sometimes their age.

BIOLOGY AND CONTROL OF TABANIDAE AFFECTING RECREATIONAL AREAS IN SOUTH CAROLINA

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Research has been conducted on Tabanidae affecting golf courses and a park located on the coast. The attractancy of these flies to colored spheres and to carbon dioxide in various traps has been studied. Larval habitats have been investigated. Tests have been conducted on control with ultra low volume amounts of insecticides applied by air and by ground equipment.

Black or blue spheres and carbon dioxide are attractive to tabanids. At the present time, technology is unavailable for the elimination of the immature forms of tabanids in or around the streams or marshes near the recreational areas. All control efforts have been aimed at the adult stage, and results indicate that short-term reduction in flight activity as measured by trap catches can be obtained by the ULV application of insecticides. Scheduled applications of pyrethrum or malathion have resulted in the reduction of the flight activity of pest species.

LABORATORY OBSERVATIONS ON THE TIMING OF FLIGHT ACTIVITY IN MOSQUITOES

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Observations on the mosquito *Aedes aegypti* (L.) led me to conclude that within a certain range of photoperiods the phase-setting effects of light-on and light-off reinforce each other. This range coincides with that usually encountered by *A. aegypti* throughout its natural geographical range.

I went on to study the behaviour in different photoperiods of a further three strains of *A. aegypti* and several other species obtained both from laboratory colonies and from field collections of larvae or adults. Besides strengthening my concept that the mechanisms (probably circadian rhythms) controlling the daily pattern of flight activity play a basic part in the adaptation of a mosquito species to its geographical range, these studies also showed clear differences between long and short-day populations of temperate zone species and in the case of two arctic species indicated a greater involvement of phase-setting by light changes than has been previously suggested.

THE POPULATION DYNAMICS, PARITY PROFILES AND INFECTION RATES OF THE TABANID VECTORS OF *ELAEOPHORA SCHNEIDERI* (FILARIIDAE) IN CALIFORNIA

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Research at a field station 160 km N. of San Francisco revealed that both *Hybomitra procyon* and *Tabanus monoensis* served as vectors of *E. schneideri* (Filariidae) to black-tailed deer, *Odocolius hemionus columbianus*. Incidence of infection increased with host age with nearly 50% of deer over 3 years being infected. The worm was very rare in animals less than a year old.

CO_2 trap studies over a 3-year period revealed that *H. procyon* served as an early spring vector (before fawns are born) and, that after a vector-free period of about 2 months, *T. monoensis* served as a summer-fall vector. Infection rates of parous females revealed that nearly 30% of the *H. procyon* and about 20% of the *T. monoensis* had infective or developing stage larvae of *E. schneideri*. The maximum number of gonotrophic cycles completed was 3, and in early spring infective filariae occurred only in 2-parous females.

CURRENT RESEARCH ON THE ETHOLOGY AND CONTROL OF TRIATOMID VECTORS OF CHAGAS' DISEASE

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Some 7 million people in S. America are affected by Chagas' Disease, for which there is no satisfactory cure. Prevention by vector control is therefore paramount and house-spraying with BHC is usually employed. Resistance is a real threat and has been confirmed in one vector, so that alternative control measures must be explored.

An integrated research programme has begun at the London School of Hygiene and Tropical Medicine and involving a field laboratory at San Salvador State, Brazil, with Wellcome Foundation support. The entomological projects involve behaviour in seeking blood meals, pheromones and light reactions in relation to trapping, research on resistance and alternative chemicals and hormones as possible control agents.

VITAL STATISTICS OF *RHODNIUS PROLIXUS* (HEMIPTERA: REDUVIIDAE), UNDER LABORATORY CONDITIONS

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Rhodnius prolixus is the main vector of the Chagas' Disease in Venezuela. Vital statistics and population parameters of this species, obtained from cohort experiments under constant laboratory conditions (26 ± 1°C and 60 ± 10% R.H.), were calculated; the former involved evaluation of egg hatching, nymphal developmental time and mortality, adult male and female longevity and mortality, and female fecundity; the latter were represented by life expectations, intrinsic rate of natural increase, generation time, reproductive value, finite rate of increase, and stable age distribution. The numerical values of these parameters were interpreted both in terms of population dynamics and control strategies. The importance of age distributions, reproductive values, and dispersal to design control strategies is pointed out. A final consideration is made relating the population parameters and the fitness of *R. prolixus* to its man-made environment: it is concluded that this species can be considered a "K-strategist". The results are compared with similar information available for *Triatoma infestans*.

BIOLOGY AND ETHOLOGY OF SOME SPECIES OF TRIATOMINAE (HEMIPTERA: REDUVIIDAE)

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The biology and behaviour of most Triatominae is poorly known and only some information is available on a few species, particularly on those associated with man. A few general conclusions are to be drawn from our own and others' studies: the tolerance of some species to relative humidities and high temperatures varies considerably; so do the biotic potential, the life cycle period and aggressiveness. These differences explain, to some extent, the relative abundance, geographical distribution and potentialities of these insects. One species, *T. dimidiata* is common in human dwellings in Costa Rica, where nymphs camouflage themselves by throwing dirt grains over their bodies, but is still well represented in wild habitats, particularly associated with opossums. Detailed studies with this species have been carried out in the laboratory. Information on this and other species *(T. nitida, T. spinolai, Dipetalogaster maximus)* will also be presented.

AN ECOLOGICAL STUDY OF *OESTRUS OVIS* LINNE

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The ecology of the cosmopolitan sheep bot fly, *Oestrus ovis* L., was investigated to elucidate the effects of host age and environmental temperature upon harbored larvae; the effects of temperature and relative humidity upon pupae; natural mortality during immature stages; natural intensity and incidence of infestation in sheep; and naturally occurring generations per year in Kentucky, U.S.A.

Larvae harbored by lambs maintained at a higher temperature had a greater survival rate and matured more rapidly than larvae harbored by lambs maintained at a lower temperature. Larvae matured more rapidly, and in greater quantities, in lambs than in yearlings.

Although relative humidity had no influence upon the number of adults emerging from pupae, temperature did. Pupae subjected to a temperature below 0°C for brief periods survived, while constant temperatures below 16°C and above 32°C were fatal. A constant temperature of 16°C permitted development of pupae but inhibited emergence of adults.

SEASONAL OCCURRENCE OF *HYPODERMA* (DIPTERA: OESTERIDAE) WARBLE FLIES IN BAGHDAD AREA, IRAQ

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For two calender years, between January 1970 and December 1971, weekly visits were paid to the main slaughter house of Baghdad City searching for *Hypoderma* (Diptera: Oesteridae) warble flies infesting cattle, goats, sheep, water buffalo and camels. The search for the maggots was carried out on hides, on carcasses and on the backs of yet unslaughtered animals. The infestation was found only in cattle and goats and on one occasion only on sheep. The water buffalo and the camel were found uninfested. The maggots were present between November and April and absent between late April and October of each year. The highest infestation among cattle was 23.0% and among goats was 27.3%. On a few occasions, some dead and shrivelled maggots were found on the carcasses during the summer months.

SECTION NO. 12

AGRICULTURAL ENTOMOLOGY

CONVENOR: G. PASFIELD

REVOLUTION IN PEST CONTROL TECHNOLOGY PAVED THE WAY FOR GREEN REVOLUTION

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The revolution in pest control technology was ushered in during the forties with the discovery of the insecticidal properties of DDT by Paul Muller awarded the Nobel Prize in 1948. The present contribution tries to trace the steps by which this revolution of the forties paved the way for the Green Revolution of the sixties for which Norman E. Borlaug was awarded the Nobel Prize in 1970. The earlier revolution enabled the plant breeders to detect and select the high yielding genotypes which earlier used to be rougued out by pests, and it also enabled the agronomist to obtain economic response of much higher doses of nitrogenous fertilizers which earlier used to be masked by increased intensity of pest infestation associated with high doses of these fertilizers. These two main phenomena taken together constitute the genesis of the "green revolution". An urgent need has now arisen for bringing about another revolution in pest control technology to replace the present pesticidal umbrella with that of Integrated Control.

EDUCATIONAL COMPETENCIES NEEDED FOR CONTINUED USE OF INSECTICIDES

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The role of insecticides in world agriculture and health is challenged because of problems attributable largely to use patterns. General acceptance and minimal complications can be assured by stringent programmes of education. Proposals are made to identify categories of users, degrees of competence and methods of accomplishing training programmes. A proposal is made to seek and establish standards on an international basis.

THE FUTURE OF COTTON PEST CONTROL IN UGANDA

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Cotton, Uganda's second largest export, is grown on an estimated 800,000 hectares, almost all in small plots of less than one hectare. This crop is attacked by a succession of pests, starting with *Taylorilygus vosseleri* (Pop.), followed by the bollworms and stainers *(Dysdercus* spp.). Farmers are recommended to use DDT to control the lygus and early bollworm attacks and over 300,000 acre packs of DDT are subsidised by Government and sold to cotton farmers each year.

Alternatives to DDT are being urgently sought. More expensive insecticides in more intensive spraying regimes increase yields, but the extra cost will deter most farmers. The selection of cottons resistant to lygus attack is being attempted and early selections show promise. Lygus resistant cotton would not require early DDT use and, as the natural enemies of bollworms rapidly increase on unsprayed cotton, acceptable yields may be obtained with little or no insecticide use.

OBSERVATIONS OF COWPEA (*VIGNA UNGUICULATA* (L.) WALP.) (LEGUMINOSAE: PAPILIONACEAE) INSECTS AT THE INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE

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The I.I.T.A. legume entomology work consists of (1) identification and enumeration of pest species, (2) estimation of damage and losses due to insect attack, (3) screening and manipulation of plant germ plasm for resistance to insects, (4) technical and economic evaluations of chemical control measures, (5) agronomic and cultural control, and (6) observations on the natural enemies of the pests.

PLANT PEST CONTROL ON THE INTERNATIONAL FRONT

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During post-war rehabilitation of agriculture, plant protection played an important role, partly because of the assistance provided by the United Nations agencies, bilateral aid programmes and philanthropic foundations. Progress has been made mainly in four areas:

1. Inter-governmental cooperation in preventing the spread of plant pests. An International Plant Protection Convention providing concerted quarantine and other measures came into effect in 1951, now with 61 governments participating.
2. Development and promotion of effective and rational pest control procedures. Development of effective techniques for regulating pest populations through the integrated use of compatible methods based on ecological considerations has been accelerated.
3. Safeguarding the use of pesticides. FAO in collaboration with WHO initiated in 1959 a pesticide programme to study safety aspects in pesticide use for guidance of governments and the public, with major emphasis on pesticide residues in food, measures for regulating pesticide marketing and use, specifications, and pest resistance.
4. Assistance in combatting major pests. Assistance provided to many countries has yielded significant results in pest control, e.g. suppression of the desert locust since 1963, and through pest control research by organisations such as Rockefeller and Ford Foundations and FAO.

BREEDING FOR HOST PLANT (SORGHUM) RESISTANCE TO SORGHUM SHOOT FLY, *ATHERIGONA VARIA SOCCATA* RONDANI, IN EAST AFRICA

D. Barry

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Seedling resistance was demonstrated in Uganda in ten lines of sorghum, *Sorghum bicolor* (L.) Moench, selected from the Maldani source in India.

Tolerance or "recovery resistance", has been established in several lines of sorghum adapted to some Uganda conditions. The sources of this resistance were primarily Namatara, a local beer variety and Serena, a variety developed in the East African sorghum breeding program.

In initial selection programs, these two types of resistance are not simultaneously compatible since seedling or primary resistant plants are not attacked by sorghum shoot fly and recovery resistance requires that the plants be attacked. Both types of resistance are relative, depending upon the density of the population of flies in the testing area.

NOVEL JUVENILE HORMONE ANALOGS WITH HIGH ACTIVITY AND PROMISE FOR SELECTIVE PEST CONTROL

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A new group of conjugated dienoates combines high JH activity with several other desirable features that are essential for consideration as pest control alternatives. Order specificity can be introduced by permutations in the ester function and terminal (11-) substituents. The described structures do not require the relatively unstable epoxide function that is essential for activity in most other JH analogs. Vertebrate toxicity is negligible.

These JH analogs have the usual JH effects on metamorphosis and embryogenesis, but a number of other side effects on larval molting, adult longevity, fecundity, delay of pupation, pigmentation, etc. have been noted that have to be taken into account for evaluation of the total impact on insect populations.

Compound I, Ethyl 3,7,11-trimethyl-2, 4-dodecadienoate (ZR 0512), is specifically active on Lepidoptera, some Coleoptera and several Homoptera (particularly aphids and scale insects) but has low activity on Hymenoptera and Heteroptera.

Compound II, Isopropyl 3,7,11-trimethyl-11-methoxy-2, 4-dodecadienoate (ZR 0515), is specifically active on Diptera and bears promise as a larvicide for mosquitoes and flies.

AN INTERNATIONAL ENTOMOLOGY ORGANIZATION FOR TEENAGE YOUTH

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Teenage youth in most countries have little opportunity to explore in any depth, the science of Entomology. Those that are keenly interested have difficulty in finding young people, in their own age group, to share their interest. To find people, both locally and foreign, helps to stimulate their continued interest. The Teen International Entomology Group has supplied this need and established a publication called the TIEG Newsletter. It began in the United States in 1965 and currently has members in 33 countries. The Group represents an educational program sponsored by Cornel University, the Entomological Society of America, the Entomological Society of Canada and the American Mosquito Control Association. TIEG members run their organization through newsletter editors. They select the news and prepare the articles that are most meaningful to their age group.

This paper is being offered for presentation to inform Congress members of this educational program. It demonstrates a way of bringing to the attention of teenage students and their teachers, some of the facets of Entomology that are most appealing to youth as well as the general public. A friend of TIEG and an editor of a British Journal writes that "societies of this nature, besides widening the outlook of their members beyond their parochial borders will do more towards world peace than all the party politicians in the world, by inspiring personal friendships, which by their common interests, will outlast many years and survive strains which would disrupt mere treaty friendships."

STUDIES ON EFFECT OF THE GROWING STAGES OF RICE PLANTS ON GALL FORMATION AND LARVAL DEVELOPMENT OF THE RICE GALL MIDGE (CECIDOMYIIDAE: DIPTERA) IN THAILAND

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and Precha Vungsirabutr

Rice Protection Research Center, Bangkok, Thailand

The present study was planned to determine the susceptible growing stage of rice plants, which are severely damaged by the rice gall midge to indicate a suitable timing of insecticidal application for its control.

The seven growing stages of rice plants were inoculated with eggs. Numbers of the newly-hatched larvae showed no difference in the different growing stages of rice plants. Survival rate of the larvae was significantly higher in 28 and 46 day old plants, but mortality of the larvae became higher in rice plants more than 56 days after sowing. The larvae could not develop on rice plants formed primordium. The galls were abundant in number in 28 and 46 day old plants. It was demonstrated that the larva damage was more severe in the vegetative growing stages than in the generative growth period.

It was indicated that the timing of the first insecticidal application should be 14 days after transplanting. This method has the added advantage of protecting the natural enemies of the rice gall midge.

STUDIES OF THE LIFE CYCLE OF THE BIG MOTH BORER, *PHRAGMATAECIA CASTANEAE* HÜBNER, COSSIDAE, AND ITS DESTRUCTION OF SUGARCANE IN WEST MALAYSIA

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The Johore Sugar Plantations and Industries Berhad, West Malaysia

Sugarcane growing which is a new industry in tropical West Malaysia was first introduced by the Johore Sugar Plantation and Industries Berhad in 1969. In this company's six plantations of about 6,000 acres, big moth borer, *Phragmataecia castaneae* Hübner, is a serious pest. In a survey sugarcane 9-10 months after planting averaged 67.44% bored stalks and 9.38% bored internodes and 13-14 months after planting averaged 92.3% bored stalks and 55.24% bored internodes.

The life cycle of *P. castaneae* takes 10 to 12 days in the egg stage, 74 to 94 days in the larval stage and 2 to 6 days for adults. One female might lay 400 eggs or more and eggs were 49% parasitised by an egg parasite, *F. eulophidae*.

RESEARCH INTO *ONCOPERA* SPP. (LEPIDOPTERA: HEPIALIDAE) AS PESTS OF PASTURE IN NORTH QUEENSLAND

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All life history stages of *Oncopera mitocera* (Turner) and *Oncopera brachyphylla* Turner can now be readily identified and separated in the field.

Oncopera were reared in the laboratory for the first time from egg to adult. Provision of debris rather than fresh green food material was the important factor in the laboratory rearing success.

Success with the rearing technique allowed information on Weekly Dry Matter (D.M.) Food Consumption to be obtained for the larvae over a range of temperatures. This was then, by means of field trials, related to pasture D.M. loss at varying *Oncopera* spp. larval populations.

By means of field and laboratory studies detailed information was obtained on the temporal incidence of all life history stages in the field, fecundity, moth emergence from the pupa, time of the crepusular flight, moth mating and oviposition behavioural patterns, number of instars, specific larval burrow types, larval behaviour, and distribution of *Oncopera* spp. in North Queensland.

SEASONAL HISTORIES AND HOSTPLANT RELATIONSHIPS OF ACRIDIDAE (ORTHOPTERA) INHABITING A TALL GRASS PRAIRIE IN EASTERN KANSAS (U.S.A.)

H. Knutson, J.B. Campbell, W.H. Arnett, J.D. Lambley and O.K. Jantz

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Nine pastures, with 42 grasshoppers and 108 plants, varied in grazing time and intensity, and time when spring-burned. Range sites were Ordinary Upland, Clay Upland, and Limestone Breaks on hillsides.

Plant ingestion, determined by fragments in grasshopper's crop, is correlated to plant availability among 17 habitats.

Grasshoppers predominated in heavily grazed and early burned pastures and in Clay, then Ordinary Upland sites.

Example: overall ingestion by *Syrbula admirabilis: Bouteloua gracilis* > *Sorghastrum nutans* > *Andropogon scoparius* > *Andropogon gerardi* > *Bouteloua curtipendula* > *Sporobolus asper;* 6% Limestone Breaks, 78% Clay Upland. When present: *B. gracilis* > *S. asper* = *S. nutans* > *B. curtipendula* > *A. scoparius* > *A. gerardi.*

Eritettix simplex first instars appeared in mid-July (overwinters as nymph) and adults third week of April. *Chortophaga viridifasciata* develops earlier, and *Pardalophora haldemanii* later. All others overwinter as eggs. Only *Melanoplus femurrubrum femurrubrum* has 2 generations. *Melanoplus confusus, Hesperotettix speciosus* and *H. viridis pratensis* hatched third week in April, the remainder in May.

FACTORS AFFECTING THE SURVIVAL AND MULTIPLICATION OF WHEAT BULB FLY, *LEPTOHYLEMYIA COARCTATA* (FALL.), A PEST OF WINTER WHEAT

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Wheat bulb fly, with one generation a year, lays its eggs on bare soil. The newly hatched larvae have to find a host plant, enter it and feed in it; pupation occurs in the soil and the flies emerge in the summer. Fifteen per cent or less of the eggs laid suceed in completing the life cycle. Small predators such as *Bembidium* spp., *Trechus* spp., may eat the eggs. Some larvae fail to find a host plant and there may be insufficient plants to complete the growth of the larvae so the migrating third instar may die. Parasitic hymenoptera, e.g. *Phaenocarpa livida* Hal. and Staphylinids, *Aleochara* spp., attack pupae and emerging flies pushing up through the soil are vulnerable to many active carabids. Female flies feed on aphid honey dew for sugars and fungal spores for the protein necessary for the maturation of the eggs, and are commonly attacked by the fungus, *Entomophthora muscae*. The number of eggs a female lays depends whether the fungal attack is before the laying of the first batch of eggs. Many biological factors therefore help to control population of wheat bulb fly.

LABORATORY OBSERVATIONS ON THE BIONOMICS OF *ACANTHOMIA* SPP. (HEMIPTERA: COREIDAE)

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and D.S. Kettle

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Two species of *Acanthomia (A. tomentosicollis* and *A. horrida)* are pests of legumes in the Arusha district of Northern Tanzania, East Africa. This paper presents the results of laboratory investigations undertaken to assist interpretation of field observations. Studies were made of the effect of temperature (18°C, 25°C and 30°C) and host plant *(Dolichos lablab* and *Phaseolus vulgaris)* on the duration of the life cycle and nymphal survival of both species. There were significant differences between them with *A. tomentosicollis* being better adapted to *D. lablab* and the higher temperatures (25°C, 30°C) and *A. horrida* to the lowest temperature (18°C) and to *P. vulgaris*. Studies were also made on the effect of intraspecific competition on longevity and fecundity. Longevity of both sexes of *A. tomentosicollis* was independent of density but fecundity was inversely correlated with density of females. In *A. horrida* longevity of both sexes was inversely correlated with the density of the same, but not the opposite sex, while fecundity was reduced by an increase in density of either sex. The significance of these findings to field observations will be discussed.

BIOLOGICAL AND ECOLOGICAL STUDIES OF THE RICE BUG, *LEPTOCORISA ORATORIUS* (F.) (HEMIPTERA: ALYDIDAE), AND ITS CONTROL

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In Papua New Guinea, *Leptocorisa oratorius* is the main pest of rice. Both nymphs and adults attack the developing grains.

Its hosts include rice, grain sorghum and 8 other species of grasses.

Its life cycle and seasonal history have been studied. It breeds all year round and passes 7 overlapping generations per year.

Among 4 species of natural enemies, *Gryon nixoni* is the most important egg parasite.

Its population fluctuations within and outside of the rice fields have been investigated. It indicates that the population fluctuations were influenced by immigration, emigration, chemical control, food plant and egg parasitism. Stage of food plant caused *Leptocorisa* to immigrate or emigrate; amount of food, effective insecticide and egg parasitism determined population to increase or decline. From a dispersal study adults migrated 154-305 yards from release places after 7-28 days from release dates.

In a trial with 5 insecticides, the treatment with monocrotophos produced the highest yields. Yields of all treated plots were significantly higher than the untreated plots.

EGG MORTALITY OF *NEMICIA VIRIDIS* MUIR (HOMOPTERA: TROPIDUCHIDAE) IN SUGARCANE AND IN INDIGENOUS HOSTS

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Nemicia viridis Muir (Homoptera: Tropiduchidae) is an indigenous grass-inhabiting insect of Southern Africa, which in 1962 became a recognised pest of sugarcane. Its eggs, which are inserted in leaf midribs and grass stems, are attacked by two hymenopterous parasites, *Ootetrastichus ?beatus* Perkins (Eulophidae) and *Oligosita* sp. (Trichogrammatidae). From an infested field 14 monthly samples were taken of *N. viridis* eggs in both sugarcane and in adjacent indigenous hosts, and studies were made of their condition, regarding parasitisation and degeneration throughout other causes. It was found that natural egg mortality from all causes was higher in indigenous host plants than in sugarcane, and that the eulophid destroyed more eggs than the trichogrammatid. It is suggested that the lower egg mortality in sugarcane is due to the protection offered by that plant's tougher and more succulent structure, and is a contributory cause of *N. viridis* having assumed pest status.

TERMITE MOUND TEMPERATURES UNDER TROPICAL CONDITIONS

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Over a two year period continuous recording thermographs were used to record temperatures in three different types of mounds. One termite species is found in wet sclerophyll forest and the others in open woodland and grassland.

Soil and screen temperatures were recorded for comparison.

Two were found to have relatively stable temperatures while the third was subject to marked daily temperature changes.

THE PATTERN OF ENTOMOFAUNA HARMFUL TO COTTON PLANTS IN UZBEKISTAN

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Climatic conditions of Uzbekistan cotton zones are semi-desert in character. The entomofauna of cotton fields is, therefore, composed of the elements of arid and long-time irrigated lands of other zones of the Republic.

Among field plants, in particular cotton and lucerne, xeriphil and arid forms predominate, in the fields with later plant developmental stages, oasis, mesophil insect forms being predominant. The mixed patterns of arid and oasis entomofauna zones both on lands under cultivation and in their weed surroundings is marked on untilled lands.

Gradually, numerous dominant and permanent virgin soil species are ousted, or their populations greatly decrease, the number of individual species increasing. The predominance of certain species in number occurs at the expense of those which are adapted for developing on tilled lands with irrigation (they are species with a wide ecological and geographical plasticity), and, to a certain extent, due to the adaptation of some monocyclic oligophages.

In the south of Uzbekistan where extensive cultivation of a part of the desert zone has lately been under way, entomofauna harmful to cotton plants is being formed in some new conditions when historical inter-relationships of species rich primary (arid) forms have been destroyed, and the latter are confronted with species typical of agroentomocoenoses.

MIGRATION AND OUTBREAKS OF *PSEUDALETIA CONVECTA* WALKER (LEPIDOPTERA: NOCTUIDAE) IN NEW SOUTH WALES

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The sudden appearance of larval outbreaks of the common armyworm, *Pseudaletia convecta* Walk., can be partly explained by migration.

Studies on outbreak sequence in New South Wales indicate that favourable conditions exist throughout the year on the central and north coast and that adults migrate west, south west, and north west in spring and, east and north in summer and autumn.

Migration thus allows *P. convecta* to appear in areas at a time when optimum conditions occur although these areas are unfavourable for permanent existence. A number of factors support the migration theory, chief of these being the presence of phase polymorphism, absence of diapause, suddenness of outbreak appearance, definite moth flights periods at three localities, seasonal occurrence of outbreaks, restriction of outbreaks to the areas which received the specific weather conditions, delay between occurrence of predisposing weather conditions and reports of larval outbreaks, larval instar synchronization, lack of second generation outbreaks, time lag in parasite efficacy.

ESTIMATION OF LOSSES CAUSED BY PADDY BUG

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Paddy bug, *Oebalus poecila* (Dallas) and red rice cause quantitative and qualitative losses simultaneously. Results of a survey indicated that (i) paddy harvested late in season was damaged more by the paddy bug, (ii) 40% and 71% samples in autumn and spring crops respectively had more than 0.5% bug damaged grains, and (iii) 90% and 80% samples had more than 2% red rice in autumn and spring crops respectively. According to the present grading system, more than 0.5% bug damaged grains or more than 2% red rice reduce the grade of paddy. National yearly loss was estimated to be about six million Guyana dollars due to bug damaged grains and red rice and complete elimination of one of these two factors would have still resulted in a loss of about four million Guyana dollars. These data also explain why certain producers claim that control of paddy bug does not improve the grade of paddy.

SEQUENTIAL PLAN FOR ASSESSMENT OF DAMAGE BY *APHODIUS TASMANIAE* HOPE (COLEOPTERA: SCARABAEIDAE) IN PASTURES IN SOUTH AUSTRALIA

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A sequential plan is being developed to assist in determining the economics of treating *Aphodius tasmaniae* Hope, a pest causing damage to pastures, usually over large areas of South Australia in most years.

Using a 400 cm^2 sample unit, frequency distributions of field populations of mainly second instar larvae could not be suitably described for use in a sequential plan. Distribution found by reducing the sample unit size to 108 cm^2 closely fitted a negative binomial distribution and was applicable to a sequential plan.

In 1971, effects of three larval densities on ungrazed pasture were estimated by comparing lindane treated areas with untreated areas. There was a 36.4% fresh weight loss of pasture during autumn caused by the highest larval density (470 larvae per square metre), but there was no difference between treated and untreated areas for the remainder of the year. Up to 100% pasture losses occurred in areas adjacent to the trial which had similar larval densities, but were grazed. This suggested that future damage assessment studies should be made on grazed pastures.

DYNAMICS OF THE DENSITIES OF COLLEMBOLA IN THE PROCESS OF STRAW HUMIFICATION IN RELATION WITH THE LIFE ACTIVITIES OF EARTHWORMS

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The densities of Collembola and their dynamics in the process of straw humification were investigated experimentally (in the vegetative pots) during 1969-1971. Besides the straw addition the pots had various amounts of earthworms *(Allolobophore caliginosa* Sav. f. *typica)*.

The amounts of Collembola increased in the pots from several hundred up to several thousand specimens as compared with their numbers in the natural soil or in the soil unfertilized. In the straw layer Collembola were 10-100 times more numerous compared with their quantities in the soil. Greater densities of Collembola were found in the straw at the beginning of straw decomposition (i.e. in the first-third months). Later on (4th-6th month) Collembola are decreasing and at the end of decomposition (i.e. after 10-12 months) they almost totally vanish.

Owing to the effect of earthworms and other invertebrate animals the straw decomposes 2-5 times faster than usual.

Specific composition of Collembola varies in the process of humification, one species dominating at the beginning and the middle period and the others being dominant at the end of the humification.

THE SIGNIFICANCE OF TERMITES IN THE CYCLING OF SOIL ORGANIC MATTER

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Termites are primarily soil-inhabiting animals and feed on plant material, living or dead, partly or almost entirely decomposed.

Symbiotic micro-organisms enable them to attain high assimilation efficiencies (50-70%) and to digest up to 90% of total carbohydrates. Some species apparently digest lignin (up to 80% assimilation has been recorded). Their excreta is used as a constructional material or cement and contains little that can be further decomposed by micro-organisms.

Populations in sub-tropical and tropical soils may reach 10000/m^2, biomass 50 g/m^2, and total termite metabolism about 100 k cal/m^2/year. This is of the same order as the metabolism of the largest known populations of wild herbivorous mammals.

The combination of high assimilation efficiency, large populations and foraging with accumulation of food and excreta in concentrated nests has great significance in the cycling of organic matter and plant nutrients in soils.

A LEAFROLLER *SPARGANOTHIS PUTMANANA* FREEMAN, TORTRICIDAE, AS A NEW PEST ON BIRDSFOOT TREFOIL *LOTUS CORNICULATUS*

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During 1967 populations of a leafroller *(Sparganothis putmanana* Freeman, Tortricidae) were first observed in the Champlain Valley of Vermont, damaging fields of birdsfoot trefoil, *Lotus corniculatus*, grown for seed.

Developing larvae destroyed the growing point of the plant with a resulting loss of seed yields. Populations fluctuated over subsequent years with little economic injury in 1971. Causes for diminished populations are not fully understood, and the impact of the cultural, chemical and biotic factors, employed or observed, are considered. The insect has been successfully reared in the laboratory on artificial media.

INSECT PROTEIN IN FOOD RECYCLED FROM SEWAGE LAGOON BIOMASS

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A properly designed sewage lagoon system produces significant growths of filamentous algae and water plants in the second pond. The efficiency of a lagoon system was demonstrated chemically, as was the process of conversion of this biomass to material suitable for animal food. A major fraction of the biomass was insects together with other invertebrates. Recycling of sewage lagoon biomass results in clean water as affluent, as well as a potential animal feed of nutritional quality. Protein levels are much higher than that of alfalfa meal, while nitrates and nitrites are very low in comparison. Since nitrates can convert to nitrites in the gut of mammals, and since nitrite can react with hemoglobin to form methemoglobin (cause of the disease methemoglobinemia), this low nitrate/nitrite content of sewage lagoon biomass can be of particular value in fortifying alfalfa meal to increase protein and reduce the percentage of nitrites and nitrates. Entomologists will appreciate that insect protein is nutritionally available. Furthermore, this insect protein is a new potential source of protein for domestical animals, and hence for humans at the end of the food chain. As the human population increases (with consequent increase in sewage) sewage lagoon biomass should become a new agricultural crop.

AN INVESTIGATION ON *HEDYLEPTA (NACOLEIA) DIEMENALIS* WALKER (LEPIDOPTERA: PYRALIDAE) AS A PASTURE PEST IN SOUTH EAST QUEENSLAND

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The leaf rolling pyralid moth *Hedylepta diemenalis*, not widely regarded as a pest in Australia, is described causing damage to *Desmodium* based pastures in south east Queensland. The geographical distribution, host range, pest status outside Australia, and reports of damage in Queensland are given. A method of estimating damage by *H. diemenalis* and other leaf damage is described. The results of sampling from *Desmodium* based pasture at University of Queensland Research Station, Mt. Cotton are given and discussed. *Desmodium intortum* showed greater total leaf damage by insects, greater damage by *H. diemenalis* and larger larval populations of *H. diemenalis* than *D. uncinatum*. Host plant resistance to insect attack is suggested as the cause of these differences. On the basis of reported cases of damage by *H. diemenalis*, it is regarded as a minor pest of *Desmodium* based pastures in south east Queensland. The future pest potential of the insect and possible approaches to control are discussed.

CHEMICAL CONTROL OF COCONUT CATERPILLAR, *BRASSOLIS SOPHORAE* AND MOTH BORER, *CASTNIA DAEDALUS*, MAJOR PESTS OF COCONUT

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Continuous stripping of leaves by the caterpillar results in death of some palms while the others do not bear any nuts. Injection of 60% monocrotophos E.C. at 3.6 gm a.i. in one hole per palm gave complete kill of the caterpillar. The treatment was effective for at least 72 days and was thus suited for control of overlapping generations of the pest. Further, in view of the natural abundance of insect parasites, injection rather than spraying of palms, suggests itself. One man can inject 150-170 palms (1.3 ha) per day.

Moth borer generally tunnels the trunk near to leaf bases and thus leaves and trusses shed prematurely. The infested palms bear about 54% as much nuts as uninfested ones. Egg, larval and pupal stages lasted 17, 315 and 35 days respectively. Injection of 3.6 to 6.0 gm monocrotophos in three holes per tree killed the borer larvae in trunk. In an area where larvae remained in leaf bases rather than in the trunk, the larvae were not killed by this technique.

RELATIVE SUSCEPTIBILITY TO ENDRIN OF *SPODOPTERA LITTORALIS* BOISD. AND AN ASSOCIATED ENTOMOPHAGOUS BEETLE AS INFLUENCED BY FIELD APPLICATION

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Samples of *S. littoralis* larvae and *Coccinella undecimpunctata* (beetles) were collected from cotton fields at the beginning and towards the end of the season. The toxicity of endrin to both species was estimated in both samples and the field application of the insecticide during the season was recorded. The obtained LD_{50} values indicate a slight increase in tolerance of both insects to the used insecticide due to field application.

FUMIGATION AS A METHOD OF CONTROLLING DRY-WOOD TERMITES (KALOTERMITIDAE)

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Kalotermitidae live inside their food supply eating the wood as they go along, with little or no connection with the ground at any stage of their development. *Postelectrotermes militaris* (Desneux), *Noetermes greeni* (Desneux) and *Glyptotermes dilatatus* (Bugnion) colonize the heartwood of the tea plant. These termites cannot be controlled with either systemic or persistent non-systemic insecticides. Several fumigants were evaluated by introducing each through a hole drilled into the gallery system. Aluminium phosphide, ethylenedibromide, trichlorobenzene, para-dichlorobenzene and dichlorvos gave good results. Ethylenedibromide and trichlorobenzene were phytotoxic and results with para-dichlorobenzene and dichlorvos were inconsistent. Aluminium phosphide, available for grain fumigation as "Phostoxin" in tablet or pellet form, gave excellent control with absolute kill in many instances. Phostoxin generates phosphine gas when exposed to moisture, leaving aluminium hydroxide as a harmless residue. Doses of Phostoxin, ranging from 0.15g to 1.2g depending on the termite species and size of tea bush, were used successfully without adverse effects.

NEW METHODS OF LOCUST CONTROL

P.E. Köhler

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Presents a new method of antilocust fight by means of temporary destructión of the ecosystem killing locust and drying the vegetation. Within the dunes applications of lattice spraying with residual locusticides.

EFFECTIVE CONTROL OF TWO SPOTTED MITE AND EUROPEAN RED MITE IN AUSTRALIA WITH PLICTRAN^R, WITH REFERENCES TO SPECIFIC ACTIVITY

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Imperial Chemical Industries (Australia) Limited, Sydney, N.S.W., Australia

Results are given of extensive trials of Plictran^R (Tricyclohexyltin hydroxide) in Australia from 1967 to 1969 which established that 3 ounces Plictran^R a.i. per 100 imperial gallons gives effective control of two-spotted mite *Tetranychus urticae* (Koch), and European red mite *Panonychus ulmi* (Koch).

In Australia the laboratory contact assessment method of Colburn and Asquith (1971) giving higher mortalities than those likely to occur in the orchard has shown that the commercial dosage of 3 ounces Plictran^R a.i. per 100 imperial gallons (0.01875% w/v) gives survival of *Stethorus vagans* Blackburn, *S. nigripes* Kapur and *S. loxtoni* (Britton).

ULTRA-LOW VOLUME SPRAY APPLICATION ON COTTON IN MALAWI

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Farmers in Africa often have only one or two hectares of cotton and use knapsack sprayers to apply insecticides in 56-224 litres of water per hectare. In Malawi, spraying farmers have obtained yields averaging 1000 kilogrammes of seed cotton per hectare. As water supply is a major problem, ultra-low volume application with a small battery driven spinning disc sprayer is being evaluated, with encouraging results. 25% carbaryl and 40% DDT, to control *Diparopsis castanea* Hmps. and *Heliothis armigera* Hbn. respectively, with dimethoate added when required as aphicide/acaricide, are applied according to assessments of insect populations by routine scouting. Spray is fed to the spinning disc at 0.5 ml/sec. and swathe width decreased from six rows to two rows during the season. On a two row swathe (1.8 m) when plants exceed 50 cm height, 2.5 litres of spray are applied per hectare.

THE USE OF SOUND AND LIGHT TO CONTROL THE BOLLWORM MOTH

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High frequency sound (10 to 100 kHz) and light (400 to 700 nm) were evaluated as stimuli to interfere with the normal behaviour of the bollworm moth and prevent economic damage to cotton. 1. The sensitivity of the acoustic and visual receptors to (a) frequency and (b) stimuli intensity was determined using electrophysiological techniques. 2. Behavioural responses of the field-collected and laboratory-reared moths to known stimuli were evaluated in the laboratory. 3. The most promising stimuli pattern for elicting evasive behavioural responses were evaluated in the field. 4. The most efficient system for eliciting moth evasive behaviour was then tested in the field under heavy population pressures. It was found that the moth habituation to the sound and light stimuli occurred after 5 to 10 minutes; it was also found that about 10% of the moths were unresponsive to the stimuli under all circumstances. Therefore, apparently normal feeding, mating, and ovipositing occurred in the moth population at such levels that economic control was not achieved.

LABORATORY AND FIELD TECHNIQUES FOR TESTING THE EFFECT OF PESTICIDES ON HONEY BEES

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During the past 20 years the LD_{50} values have been determined for more than 300 pesticides on honey bees in the UCR entomology laboratory. An additional 70 pesticides have been evaluated for toxicity to bees in the field. Laboratory tests are made by a vacuum dusting technique under uniform conditions. Field tests are made by treating over bee colonies in 16 acre size alfalfa plots using sprays by airplane. In the field tests effects are measured by evaluating colony strength, recording dead bees collected in a Todd Dead Bee Hive Entrance Trap, bee field visitation records, mortality of caged bees in treatment areas and bee bioassay of residues on foliage.

SECTION NO. 13

FOREST ENTOMOLOGY

CONVENOR: F.D. MORGAN

FOREST INSECT PROBLEMS IN THE SOUTH PACIFIC ISLANDS

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Forest insect pest problems encountered in the South Pacific Islands of Papua New Guinea, Fiji, Western Samoa and in the British Solomon Islands are considered in this report. The three most serious problems are: 1. the large scale infestation of Hoop Pine plantations at Bulolo and Wau in Papua New Guinea by a branchlet mining scolytid, *Hylurdrectonus araucariae* Schedl; 2. the infestation of Mahagony plantations in Fiji by ambrosia beetles; and 3. a high incidence of ambrosial beetle attack in newly felled logs and timbers throughout the islands and subsequent downgrading for export and local sale. There appears to be no serious forest insect problems in the Cook Islands, American Samoa, Tonga, Gilbert and Ellice Islands, French Polynesia, New Caledonia, Wallis and the Futuna Islands, and in the U.S. Trust Territorities.

APHID-FOREST RELATIONSHIP IN TURKEY (APHIDOIDEA: HOMOPTERA)

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The members of the superfamily of Aphidoidea are an economically important group of insects in Turkish forests. Almost one hundred species have been found on forest trees in Turkey, which belong to the families Lachnidae, Chaitophoridae, Callaphididae, Aphididae, Thelaxidae, Pemphigidae, Adelgidae (Chermesidae), and Phylloxeridae.

In Lachnidae, especially *Cinara cedri* Mimeur on *Cedrus libani*, and *C. palaestinensis* Hille Ris Lambers on *Pinus brutia* are very important species. All the Chaitophoridae live on *Acer*, *Populus*, and *Salix* species. In Callaphididae, *Phyllaphis fagi* (Linnaeus) on *Fagus orientalis* and *Pterocallis alni* (DeGeer) and *P. maculata* (von Heyden) on *Alnus glutinosa* may be mentioned.

The family of Aphididae has also some important species, such as *Aphis craccivora* Koch on *Robinia pseudoacacia*, and *Elatobium momii* (Shinji), an East Palaearctic species, on *Abies bornmülleriana*.

In Thelaxidae only *Mindarus abietinus* Koch on *Abies bornmülleriana* and *A. nordmanniana* are important. Most of the species of Pemphigidae are gall-makers and leaf-rollers. *Eriosoma lanuginosum* (Hartig) is the best known aphid in this family, on *Ulmus* species. *Prociphilus fraxini* (Geoffroy) on *Fraxinus oxycarpa*, *Pemphigus lichtensteini* Tullgren and *P. protospirea* Lichtenstein on *Populus nigra* var. *pyramidalis* are important species.

The three species of Adelgidae (Chermesidae) cause galls on *Picea orientalis* in Turkey. The galls of *Pineus orientalis* (Dreyfus) are very destructive in our East Black-Sea Region and the spring buds of the young trees are attacked by this species. The same damage in parks and gardens is caused by *Pineus pini* (Macquart), but *Adelges (Dreyfusia) nordmanniana* (Eckstein) is not important.

The family Phylloxeridae is represented only by *Phylloxera florentina* Targioni-Tozzetti on *Quercus* sp.

THE EFFECT OF DEFOLIATION BY THE LEAF MINER, *PERTHIDA GLYPHOPA* (LEPIDOPTERA: INCURVARIIDAE) ON THE GROWTH OF JARRAH

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The leaf miner (*P. glyphopa* Common) is a defoliator of jarrah, *Eucalyptus marginata* Sm., in the south-west of Western Australia. In 1971 the area of defoliation was approximately 5,000 square miles of which some 2,000 square miles were in the State Forest.

Within a stand of jarrah, approximately 23% of trees are resistant to the attack and are not defoliated. The resistant trees were used as controls in comparing the girth increment in the defoliated susceptibles. Measurements with dendrometers at breast height on three sites, each consisting of equal numbers of resistant and susceptible trees showed the following reduction of girth increment in the susceptible trees: 64% in 1968, 70% in 1969 and 54% in 1970.

PRELIMINARY OBSERVATIONS ON EUCALYPT WOOD BORERS IN ITALY

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The research started soon after 1969, when the cerambycid *Phoracantha semipunctata* F. was observed in Sardinia for the first time.

The investigation aims at establishing the number of xylophagous insects feeding at the larval stage on eucalypt in Italy, at evaluating the seriousness of the damage provoked, and at ascertaining the presence of eventual predators or parasites.

Besides *P. semipunctata* (existing in Sardinia only), the following species have been so far observed: the cerambycids *Leptura cordigera* Füessly and *Niphona picticornis* (Muls.), the buprestids *Chrysobotris affinis* (Fabr.) and *Anthaxia millefolii* (Fabr.), and the bostrychids *Botrichus capucinus* L. and *Sinoxylon sexdentatus* Oliv.

Phoracantha semipunctata is the only species causing serious damage, but I consider it desirable to conduct bioethological investigations also on *N. picticornis*, *L. cordigera* and their predators and parasites, since they can provide useful information for detecting valuable *Phoracantha* biological control methods.

TUSSOCK MOTH OUTBREAKS IN *PINUS RADIATA* PLANTATIONS OF SOUTH AUSTRALIA

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Large populations of the tussock moth, *Acyphas leucomelas* Wlk., (Lymantriidae) have caused severe defoliation of *Pinus radiata* plantations in the south east of South Australia.

This insect normally feeds on native Acacias and is not known to cause severe damage on these species.

However, severe defoliation has occurred over extensive areas of plantations on two occasions separated by several years.

After very rapid rises in population with subsequent defoliation followed by flights of large numbers of adults, the population suddenly fell. This was found to be due to parasitization of eggs by minute Hymenoptera.

ADULT BEHAVIOUR OF THE GYPSY MOTH AND SOME PARASITOIDS UNDER FIELD CONDITIONS

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Habitat selection, host searching activities, and diel rhythmicity of some parasitoids of the gypsy moth, *Porthetria dispar* (L.), in North America were investigated by exposing sticky-coated panels and hosts under various conditions in the field and by making direct observations. Parasitoids and gypsy moths varied in their responses to different colors, and also exhibited vertical stratification within the forest environment. All gypsy moth parasitoids examined were active primarily during daylight hours, but interspecific differences in diel rhythmicity occurred. The implications which these findings have for improving the control of the gypsy moth through its parasitoids is discussed. Results are also discussed as they relate to various aspects of parasitoid ecology, such as their microhabitat distribution, adult host searching activities, and dispersal behaviour.

THE ACTIVITY OF INSECT PATHOGENS AGAINST *TORTRIX VIRIDANA* L.

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The activity of various strains of bacteria of the *Bacillus thuringiensis* group and of commercial preparations manufactured on their basis against the caterpillars of *Tortrix viridana* L. has been studied.

The sensitivity of the caterpillars to bacterial cultures of *Bacillus dendrolimus*, *B. galleriae* and *B. insectus* was established in laboratory conditions.

Various concentrations of aqueous suspensions of respective commercial preparations, i.e. dendrobacillin, entobacterin-3 and insectin have been tested against caterpillars of the 2nd-3rd instars.

In all experiments the caterpillars died of toxicosis followed with septicaemia.

For the field trials use was made of preparations and the concentrations that produced the highest effect in laboratory conditions.

One per cent aqueous suspensions of insectin and dendrobacillin were tested in the nidi of *T. viridana* L. in oak-woods near Moscow.

The caterpillars on infested trees began to die on the next day after the treatment.

In plots treated by insectin and dendrobacillin the caterpillars died gradually and on the 7th day their mortality reached, respectively, 98% and 92%. After that the death of the pupae due to bacterioses was noted. In natural conditions the bacterial infection persists for a long time. Specimens taken from treated trees in 26 days and their cultures showed characteristic colonies of respective bacteria.

ESTIMATION OF THE NUMBER OF THRIPS IN A PATCH OF *EUCALYPTUS* SCRUB

R. Laughlin

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Isoneurothrips australis Bagnall lives in the flowers of *Eucalyptus* trees. Two independent sampling methods were used to estimate the adult population of an isolated patch of trees. The two estimates are compared and combined. The use of low probability statistics is discussed.

SAMPLING *CARDIASPINA DENSITEXTA* TAYLOR ON PINK GUM IN SOUTH AUSTRALIA

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Periodic sampling of *Cardiaspina densitexta* (Psyllidae) has been carried out for nine years since 1963. Since 1965 a new outbreak has developed and declined in 1972. The general quantitative aspects of this outbreak have been followed by population estimates derived from 10 twigs per site, each twig selected at random using a 6 sided die. Leaves are removed in the laboratory and lerps counted and assigned to appropriate categories. Populations parameters are then extracted.

THE EFFECT OF PEST DAMAGE ON OIL PALM PRODUCTION

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An attempt is made to provide an objective assessment of the correlation between pest damage in the oil palm and yield loss. This type of information is scarce for most crops, particularly perennial crops in the tropics or where damage does not directly affect the commercial part of the plant. Its importance to pest management strategy is discussed.

Leaf-eating caterpillar damage was simulated by removal of leaf tissue at various intensities and the effect on cropping was studied.

Rhinoceros beetle *(Oryctes rhinoceros)* caused heavy damage to young palms in a bare-ground plot, before fruiting. Early yield was compared in this and an adjacent unaffected plot.

Root-eating cockchafers *(Psilopholis vestita)* attacked palms and a replicated trial on possible control measures was carried out. Differential success led to plots of presumed differing degree of damage. Subsequent growth and yield performance is compared.

ESTIMATING SURVIVAL AND MORTALITY OF WOODWASPS WITHIN TREES

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Sampling wood for woodwasps is described and assessments for survival and mortality in the various stadia presented for *Pinus radiata* in Tasmanian plantations. The variation in parasitism and disease and the insect/tree relationships are discussed.

CONTROL MEASURES AGAINST THE PINE NEEDLE SCALE *PHENACASPIS PINIFOLIAE* (FITCH) IN QUEBEC (CANADA)

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Studies on the biology and populations of the pine needle scale *Phenacaspis pinifoliae* (Fitch), carried out during the last three years, show the poor effectiveness of parasites and predators in the control of this insect. The average parasitism by *Marietta pulchella* (Howard), *Physcus varicornis* (Howard) and *Aphytis* *mytilaspidis* (Le Baron), is only 0.58%. Similarly the predation by various coccinellids in nature is only 1.1% of the scale population. Integrated control of the scale through propagation of the coccinellid *Microweisia marginata* (Le Conte) (that destroys up to 45% of the scale populations under laboratory conditions) and the late May application of the insecticide Malathion (that destroys up to 97% of the scale) is envisaged. The possibilities of introducing European parantes i.e. *Prospeltella* and *Aphytis* sp. are also seriously considered.

AN INTEGRATED CONTROL OF *CHLENIAS PACHYMELA* (LOWER)

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Periodic serious defoliation of young *Pinus radiata* by *Chlenias pachymela* over more than 40 years has occurred in South Australia and Victoria. Investigations of the chemical and biological control of the pine looper resulted in the integration of light applications of DDT and the effects of hymenopterous parasites and entomophthoraceous fungi to give control over more extensive areas than those to which chemical was applied.

VIRGIN CALIFORNIA RED SCALE FEMALES IN TRAPS FOR DETECTION OF MALE SCALE ACTIVITY IN PLANTINGS

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Visual inspection of citrus groves to detect infestations of the California red scale, *Aonidiella aurantii* (Maskell), is not always reliable. In July 1971, the Coachella Valley Eradication District of California initiated use of the virgin female traps which have proved most effective for detection of active scale infestations, some of which were missed in visual inspections. Because of its efficiency it has largely replaced visual inspection and huge savings in survey costs are realized. Single traps spaced systematically in 1-5 acres can almost pinpoint infestations, reducing visual inspection to a small acreage. Current interest and activity in the use of this trap in California and Arizona and the project of isolation, identification and synthesization of the sex pheromone for statewide surveys will be reviewed.

TEGOLOPHUS AUSTRALIS KEIF., ERIOPHYIDAE (ACAR.) A RUST MITE AFFECTING CITRUS IN AUSTRALIA

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The brown citrus rust mite *Tegolophus australis* Keif., a pest of citrus in coastal districts, has been recorded only in eastern Australia. Hosts other than citrus are not known.

Although described as recently as 1964, *T. australis* has been present in New South Wales for a very long period and early records have been attributed in error to *Phyllocoptruta oleivora* (Ashm.) the cosmopolitan rust mite pest of citrus, which is present also.

Adult *T. australis* are brownish to salmon coloured, and broader than *P. oleivora*, which is yellow. The egg, closely appressed to the fruit or foliage surface, is helmet-shaped, in contrast to the spherical egg of *P. oleivora*.

Fruit blemish by *T. australis* is characteristic in appearance and situation, being smooth and tan-coloured, occurring on fruits on the outside of the tree and only on the outer, exposed half of the fruit surface.

Injury causing fruit blemish follows increase in mite numbers to high populations on green, developing fruits in late summer-early autumn. *T. australis* also infests mature foliage and green bark of stems, but this is rarely important.

THE USE OF PHEROMONES, BAIT TRAPS AND CONTROLLED POROSITY DISPENSERS IN CONTROLLING ARTHROPOD PESTS AND DISEASES OF DECIDUOUS FRUIT

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Droplet size was precisely controlled by using metal sleeves of controlled porosity. Through the use of the fluorescent particle technique it was determined that droplets of 20 microns were optimum for controlling pests of fruit. It was demonstrated that by employing optimum sized droplets comparable results could be obtained by greatly reduced dosages. Seasonal usage of pesticides was reduced 75% by applying pesticides only when needed as indicated by bait traps and pheromones and applying reduced dosages of pesticides through dispensers of controlled porosity, mounted on aircraft or ground equipment. Common carriers including soybean oil and dioctyl pthalate were employed for dispensing insecticides and fungicides simultaneously.

A STUDY ON THE LIFE HISTORY AND CONTROL METHODS OF RHINOCEROS BEETLE *(ORYCTES RHINOCEROS* L.) IN TAIWAN

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The rhinoceros beetle, *Oryctes rhinoceros* L. (Scarabaeidae: Coleoptera), has become the most serious insect pest of the coconut palms in Taiwan owing to the increase in planting during the past ten years. This has made the present study necessary.

The life cycle of this insect in Taiwan seems to consist of one generation per year. The results of indoor observations are as follows:

The females lay 70-100 eggs; the duration of egg-stage is 11-18 days. The larval stage lasts about 100 days including three stadia. Its pupal duration is 21-24 days. The longevity of adults is about 3-4 months, this being the destructive period of the insect. The sex ratio of this species is 0.48.

For controlling this insect, several kinds of granulated chemicals were applied to the palm trees at intervals of 2-3 months. Among six kinds of chemicals, unden granule (Bayer 39007) seemed to be the most effective one and this method was found to be quite practicable.

MONITORING ECOLOGICAL SIDE EFFECTS OF RECURRENT LARGE-SCALE FOREST SPRAYING OPERATIONS

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The spruce budworm, *Choristoneura fumiferana* is the most important forest pest in eastern Canada, and currently poses a serious threat to 30 million acres of fir-spruce pulpwood stands, in spite of recurrent spray programmes for 20 years. Annual spray programmes up to 6 million acres have checked the defoliation hazard, but have entrained ecological problems with fish, birds, other wildlife, insect pollinators and other arthropods. Administrative machinery and scientific research were established to monitor ecosystem stability and to correct adverse effects on forest resources.

To determine the norms in a balanced ecosystem, the arthropod community on fir was characterized as to species diversity, population densities and patterns of change in density. Thus the impact of insecticide was reflected in abnormally rapid changes in the arthropod community. Methods of detecting insecticides and measuring survival in parasites, predators and minor pests were developed. The ecological effects of DDT and succeeding organophosphate insecticides are compared, but so far none of the spray regimes has been disastrous. Unwanted side effects can be reduced by changes in insecticide formulation, timing and dosage, or avoided by alternative methods of pest control now under study.

EVALUATION OF INSECTICIDES AGAINST FOREST INSECT PESTS AND OTHER COMPONENTS OF THE FOREST ECOSYSTEM

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DDT and other chlorinated hydrocarbons were used until 1968, to protect forests from insect pest damage, but due to the ecological implications of chlorinated hydrocarbons, a search for safe and more effective insecticides was started as soon as side effects were recognized in the late forties. Laboratory studies of 60 insecticidal compounds belonging to the organophosphorous, carbamate and urea groups were carried out against 17 species of forest insect pests representing orders, Lepidoptera, Hymenoptera, Coleoptera and Hemiptera. Contact, residual and systemic toxicity studies were carried out on the target species and the most effective insecticides were evaluated in field for toxicity to target and non-target species i.e., parasites, predators, fish and wildlife. The residues of some of these insecticides were monitored in the atmosphere, foliage and soil. Fenitrothion is now being used in large scale operations against most lepidopterous pests and Zectran^{R}, aminocarb, propoxur and Gardona^{R} appear promising after intensive laboratory and field evaluation.

PROGRESS IN SUBTERRANEAN TERMITE STUDIES IN SOUTHERN ONTARIO

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From 1966 to 1971 a bait method of control for *Reticulitermes flavipes* (Kollar) was field-tested in Southern Ontario, as a cooperative project between Forest Products Laboratories in the United States and Canada. Effectiveness of the combined poison-attractant method, which greatly reduces environmental pollution hazard, is described.

The study focused on a termite-infested area a few miles from the border city of Windsor. With suitable culturing the brown-rot fungus, *Lenzites trabea* (Pers.) Fr., produced a natural termite-attractant element in wooden bait blocks. Some attractant baits were impregnated with the slow-acting insecticide Mirex; and some non-impregnated blocks were used in conjunction therewith as untreated natural-attractant controls, in a series of experimental plots around the termite-susceptible buildings.

Placement of the insecticide-treated baits resulted in almost immediate suppression of termite foraging in a plot area. Using the natural attractant baits, nuclei of new colonies were established. The attractant-Mirex method applied to these simulated reservoirs produced a very marked control effect, demonstrating carry-back of the slow-acting poison.

NUTRITIONAL INTERDEPENDENCIES BETWEEN CERTAIN *XYLEBORUS* SPP. (COLEOPTERA) AND THEIR SYMBIOTES - POSSIBLE IMPLICATIONS FOR CONTROL

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Four species of *Xyleborus* are cultured continuously in artificial diets in test tubes. Holidic diets have been developed for two species freed of their ectosymbiotic fungi. Pupation of these insects is dependent upon sterol provided by the mutualistic fungi. The beetles can reproduce naturally by arrhenotokous parthenogenesis, and symbiotic bacteria enable unfertilized oöcytes to mature and hatch to yield these haploid male progeny. Thus, the symbiotic bacteria have superceded sperm in the activiation of oöcytes for insect embryonic development and progeny differentiation. Disruption of either or both types of microbial symbiotes will prevent development and reproductions of these insect species.

DENDROCTONUS-FUNGUS SYMBIOSIS: NUTRITIONAL BASIS FOR EFFICIENT DESTRUCTION OF PINE

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Several species of *Dendroctonus* bark beetles possess a glandular mycangium as an invagination along the anterior margin of the pronotum. A symbiotic relationship exists between certain fungi and the mycangium, and between these fungi and developing beetles in host phloem. The southern pine beetle, *D. frontalis* exemplifies a classic DeBarian symbiosis involving mycangial fungi, the beetle, and host phloem. Fungi from the mycangium colonize progeny galleries and produce large terminal globular cells characteristic of ambrosial fungi associated with xylomycetophagous scolytids. The importance of these mycangial fungi was demonstrated in the laboratory when elimination of symbionts from the mycangium resulted in a 50% reduction in progeny and an abnormal developmental period for survivors. These results and other observations indicated that certain phloeophagous beetles actually obtain significant nutrition from symbiotic fungi.

STUDIES ON THE PHYSIOLOGICAL INTERACTIONS BETWEEN AN AMBROSIA BEETLE AND ITS SYMBIOTIC FUNGUS

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Laboratory and field studies were conducted to investigate the physiological interactions between the ambrosia beetle *Xyleborus dispar* (F.) (Coleoptera: Scolytidae) and its symbiotic fungus *Ambrosiella hartigii* Batra. A medium suitable for the symbiotic fungus, and which enabled the *in vitro* rearing of this temperate zone scolytid was developed. These cultural studies and field observations indicated a univoltine life cycle and a maturation diapause in the adult stage. Mycangial isolations from the postdiapause females yielded only *A. hartigii*. In the presence of the beetle and under specific cultural conditions fungal dimorphism occurs, and the fungus is converted from a mycelial to a yeastlike or ambrosial form. Aspects of the insect's feeding and reproduction were considered with respect to its mutualistic fungus. Experimental attempts to terminate diapause with temperature, feeding and juvenile hormone analog treatments will be mentioned.

A COMPARATIVE STUDY OF EUROPEAN WOODWASPS (HYMENOPTERA: SIRICIDAE) WITH REFERENCE TO THEIR PHYTOTOXICITY

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It is well established that *Sirex noctilio*, an introduced siricid pest of Australasian pines, is phytotoxic to living trees. The ecology of this and other European siricids has been studied to determine their relative phytotoxicity. The results demonstrate that *S. noctilio* is the only species capable of killing trees, although injections of mucus and fungus derived from the siricids, and oviposition by caged females, strongly suggest that the toxic effects are less severe in more temperate climates. In Europe, *S. noctilio* is the dominant siricid in the Mediterranean biochlimatic area, and its host trees are exclusively *Pinus*, suggesting that this species should be comparatively well adapted to its new environment.

The phytotoxic properties of *S. noctilio*, its bioclimatic compatability, and seasonal emergence in the Southern hemisphere all contribute to the serious pest status of this siricid.

THE REVIEW OF MAIN SPECIES OF BOSTRYCHIDAE AS THE PESTS OF SOME FOREST STANDS IN THE SOUTHEASTERN REGIONS OF THE U.S.S.R.

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The pests Bostrychidae (Coleoptera) cause great damage in the forests of the southeastern regions of the U.S.S.R., especially in the Middle Asia and Kazakhstan, where they attack *Elaeagnus*, *Tamarix*, *Calligonum*, *Haloxylon*, *Salsola* and *Pistacia*.

In the Astrakhan district and Kazakhstan *Enneadesmus scopini* Vurs. is widely spread on *Elaeagnus angustifolia* L. and other tree species.

In Uzbekistan this pest but *Elaeagnus* attacks *Gleditschia triacanthos* L. It injures apparently sound trees of different sizes and it is considered to be a very dangerous forest pest.

In a number of regions of the Middle Asia *Xylogenes lilatatus* Rtt. attacks *Tamarix ramosissima* Pall. and other species.

Enneadesmus sinadskyi Furs., *E. punctulatus* Furs. and *E. vicinus* Furs. bore stems and branches of *Calligonum*. These species also injure different *Salsola*.

In Turkmenia (Budkhuz) *Pistacia* is severely attacked by *Enneadesmus* sp.

In the southeastern regions of the European part of the U.S.S.R. *Bostrychus capucinus* and *Xylonites tetusus* Ol. cause great damage in the oak stands.

The life cycles of all these pests as well as their distributions are studied.

THE BIONOMICS OF *CHLENIAS* SP. (LEPIDOPTERA: GEOMETRIDAE)

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and R. Bashford

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Chlenias sp. has occurred in epidemic proportions in areas of *Pinus radiata* regeneration at Pittwater, Tasmania since 1967-68.

Factors contributing to extreme defoliation during the spring months have been stand density, a preponderance of juvenile foliage and high survival of the larval stages early in the season. Late seasonal control has been chiefly effected by a shortage of food, braconid and tachinid parasitism and a nuclear-polyhedrosis disease. Avian predation of both pupae and adults was also recorded.

Large trees were more susceptible to the effects of defoliation and many trees died while the majority were conditioned to attack by the woodwasp *Sirex noctilio* during the summer months.

LIBRARY U. OF I. URBANA-CHAMPAIGN

SECTION NO. 14

STORED PRODUCTS ENTOMOLOGY

CONVENORS: B.R. CHAMP AND S.W. BAILEY

SOME DISTRIBUTION ASPECTS OF TROPICAL STORED PRODUCTS PESTS

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Reference is made to specific cases of distribution patterns of the species of major importance as stored products pests, including *Sitophilus* spp., *Trogoderma* spp., *Ephestia* spp., *Cathartus* sp., *Tribolium* spp., and Bruchidae. Certain aspects of insect productivity are referred to indicating the inter-relationship of temperature, humidity and food environment.

A range of factors of importance in distribution patterns are discussed with examples of interspecies competition or dependence. A definition is given of storage climatic patterns (SCP), based on rainfall, harvesting date, temperatures and relative humidities; four basic SCP's are referred to covering, Guinean, Sudanian and Highland zones. Each of these is stated to be characterized by types of pest problems and areas can be predicted where maintenance of quality of produce necessitates attention to methods of reducing the moisture content of produce, controlling insect pests of stored produce and/or preventing reabsorption of moisture and thus eliminating deterioration from mites, fungi and bacteria and minimising the incidence of insect pests.

THE ABSENCE OF *TROGODERMA GRANARIUM* (COLEOPTERA: DERMASTIDAE) IN AUSTRALIA

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The natural climate of much of coastal Australia appears unsuitable for the establishment of *Trogoderma granarium*. This is shown using the climatic analysis method of Howe for the prediction of pest distribution. The method is criticised in the light of present world occurrence of khapra beetle and possible factors leading to the absence of the pest in Australia are discussed.

RESEARCH AT SAVANNAH WITH CHEMICALS FOR THE CONTROL OF STORED-PRODUCT INSECTS

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Development of new chemical control methods for stored-product insects has assumed added dimensions since the formation of the Environmental Protection Agency in 1970. Efficacy and toxicity to man and his animals are no longer the only primary considerations. The Stored-Product Insects Research and Development Laboratory, Savannah, and the other laboratories of the former Stored-Product Insects Research Branch have now reevaluated many of their recommendations and now scrutinize potential chemical pesticides in greater depth. Information on efficacy, formulations, methods of applications, toxicity, residue analysis methodology for parent and degradation products, effect on commodity quality, and general impact on total environment are now needed for registration of a new chemical.

Current research programs in fumigation, space sprays, vapors and dusts, mothproofing, and insect-resistant packaging are discussed. Examples of pesticides under investigation include phosphine, acrylonitrile, carbon dioxide, methyl bromide, dichlorvos, malathion, pyrethrins, resmethrin, Gardona, chlorpyrifos, Mobam, bromophos, propoxur, fenitrothion, and fenthion.

EVALUATION OF HYDROGEN PHOSPHIDE AS A FUMIGANT IN THE CONTROL OF *EPHESTIA ELUTELLA* HB. AND *LASIODERMA SERRICORNE* F., AND OF ITS RESIDUES ON TREATED TOBACCO BALES

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Test fumigations of tobacco warehouses with hydrogen phosphide formulated as tablets and pellets of "Phostoxin" showed high insecticidal action and could be successfully applied in the control of *Ephestia elutella* and *Lasioderma serricorne*, pests of tobacco warehouses.

A dosage of 0.2 g of PH_3 per m^3 and an exposure period of 120 hours had very little insecticidal action on tobacco moth larvae. Dosages of 0.4, 0.6 and 1.0 g of PH_3 per m^3 produced 100% mortality under all experimental conditions.

The investigations demonstrated strong phosphine penetration in all packing materials used for tobacco.

On the basis of the results of residue analysis, no traces of phosphine were found in treated tobacco.

RESPONSES OF STORED PRODUCT INSECTS TO THE FUMIGANT PHOSPHINE

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Tribolium confusum absorb phosphine rapidly, while *Sitophilus granarius* absorb it slowly. In the latter species absorption is limiting and dosage increases fail to bring about corresponding increases in fumigant uptake. The concentration - time product method of expressing the dose - toxicity relationship becomes invalid. The amount of fumigant absorbed to kill insects is approximately the same for different species. In the absence of oxygen insects are virtually immune to phosphine while in pure oxygen susceptibility is enhanced. The respiratory system seems the most likely site of action but oxygen consumption is only partially inhibited by the fumigant. Carbon dioxide reduces respiration but toxicity is increased. Sublethal doses of phosphine have a cumulative effect on insects. Some adult insects can recover from the injury produced by a sublethal dose but others appear to be permanently injured and some larvae continue to develop but may be imperfectly formed or die later. Resistance to phosphine in *S. granarius* has been selected in the laboratory and cross resistance to phosphine has been found in strains resistant to other fumigants.

CHEMICAL CONTROL OF PESTS OF PADDY IN STORAGE

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Sitotroga cerealella (Oliv.) and *Rhizopertha dominica* (Fab.) are serious pests of paddy in storage. Nine insecticides of low mammalian toxicity were tested for their duration of effectiveness on jute sacking, against the adult moth. Further, studies on the KD_{50} of more effective insecticides indicated that phoxim was the best insecticide for the control of moth infestations. In bond tests application of 0.25% phoxim at 150 mg/m^2 of stack of paddy stored in jute bags, controlled as well as prevented moth infestation, up to six months after treatment.

In laboratory tests, pirimiphos methyl was better than malathion, when admixed with paddy for protection against storage pests. In large scale tests, pirimiphos methyl at 6.9 p.p.m. controlled all storage pests for at least four months. Analysis of insecticide residues indicated that insecticide penetrated the grain during parboiling and at 6.9 p.p.m., the residues of pirimophos methyl were within safe limits.

RESISTANCE TO COMPOUNDS WITH JUVENILE HORMONE ACTIVITY IN A STRAIN OF *TRIBOLIUM CASTANEUM*

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A strain of *Tribolium castaneum*, resistant to DDT, lindane, pyrethroids, bromodan, carbamates, and organophosphorus insecticides, is also resistant to synthetic *Cecropia* juvenile hormone, and to JH analogues. Larvae of a normal and of a resistant strain were grown in flour containing JH. With increasing dose the JH produced adult mortality, pupal mortality, delay in pupation, prevention of pupation, and larval mortality, in both strains. A higher dose was required for each of these effects in the resistant strain. The resistance to organophosphorus insecticides appears to involve the O-de-alkylation of their oxygen analogues, and is not overcome by the synergist piperonyl butoxide. The resistance to JH is also probably due to enhanced detoxication. The metabolism of a JH analogue containing the methylenedioxyphenyl moiety (compound 2b of Bowers 1969) has been studied in the susceptible and resistant strains.

SEX PHEROMONES OF PHYCITID PESTS OF STORED PRODUCTS

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A sex pheromone, *cis-9, trans*-12 tetradecadien-1-yl acetate (I), was isolated from females of the following five phycitid species: almond moth, *Cadra cautella* (Walker); Indian meal moth, *Plodia interpunctella* (Hübner); Mediterranean flour moth, *Anagasta kuehniella* (Zeller); raisin moth, *Cadra figulilella* (Gregson); tobacco moth, *Ephestia elutella* (Hübner). I functions as a sex stimulant and, in some of these species, also as a sex attractant. Stimulatory and attraction studies in conjunction with electroantenogram studies with crude and purified extracts of the sex pheromone gland and with known compounds demonstrated that the sex attractant of certain of these species is composed of I and additional components. Results of these studies will be discussed along with those on other isolation mechanisms, such as precopulatory mating behavior and circadian differences in mating activity.

AN EXPERIMENTAL STUDY ON THE SUPPRESSION AND REGULATION OF AN *EPHESTIA* POPULATION BY THE ACTION OF A PARASITIC WASP, *NEMERITIS*

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Heights of the population level and shapes of the population fluctuation were studied experimentally using *Ephestia cautella* Walker, in relation to the operation of the action of its parasitic wasp, *Nemeritis canescens* Gravenhorst. Less food was consumed by the host larvae in the interacting system between host and parasite than in the single host system. Increased host finding ability of the wasp resulted in increased amplitude of population fluctuation of the host and in decreased food consumption by the host larvae. It was shown, however, that the population in the host-parasite interacting system was regulated through the density effect of the host itself as well as through the effect of their interaction. The S-shaped functional response of the parasite was noticed in the system. From this point of view the population regulation in the experimental system will be discussed as a model of natural insect populations.

THE SUCCESSION OF PHYCITINAE (LEPIDOPTERA: PYRALIDAE) ATTACKING CAROBS (*CERATONIA SILIQUA* L.) BEFORE AND AFTER HARVEST IN THE MIDDLE EAST

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Carob tree flowers attacked in August by the cecidomyid *Eumarchalia gennadii* Marchal produce stunted pods. Emergence holes left in April and May provide oviposition sites for the moth *Ectomyelois ceratoniae* Zeller. Normal pods are not attacked by insects until fully grown and then only those which crack, probably due to differential stresses (carobs are indehiscent) during ripening in June-July.

A mould, *Phomopsis* spp., infects these cracks and attracts adult *E. ceratoniae* emerging from the stunted pods, Gothilf 1964. *Ephestia calidella* Guen. and *Ephestia figulilella* Gregs. also develop in these cracked pods. After harvest (August) emerging *E. ceratoniae* adults disperse and breed mainly on fallen carobs, citrus and other fruits in the field. *E. calidella* and *E. figulilella* persist during storage as diapausing larvae, emerging the following June-July. *Ephestia cautella* Walk. the major storage pest breeds mainly on these previously infested cracked pods, increasing rapidly in numbers during August to October; low temperatures restrict further increase until Spring.

HAMMERMILLING MAIZE GRAIN TO CONTROL INSECTS INFESTING FARM-STORED ANIMAL FEED

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A physical method of insect control, the reduction of losses of maize stored for animal feed by the use of a hammermill, was investigated in 1964-67. Maize grown in coastal areas of New South Wales is subject to field infestation by maize weevil, *Sitophilus zeamais* Motsch., and Angoumois grain moth, *Sitotroga cerealella* (Oliv.), and serious post-harvest loss of grain may result.

Control of these insects by processing infested maize with a hammermill, used on dairy farms in these areas to prepare maize for feeding to animals, was demonstrated. Five hundred bushels of insect-infested maize was hammermilled and stored in bulk at Grafton. Surface material became infested by insects during 12 months' storage, but insect activity in subsurface samples was relatively slight.

A change of farm practice in maize storage, utilizing the hammermill as a non-insecticidal means of insect control appeared of benefit for reducing loss of stored animal feed.

THE PLANNING AND ORGANIZATION OF MEASURES DESIGNED TO PREVENT AND CONTROL INSECT PESTS IN A MAJOR PRIMARY INDUSTRY

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Prevention and control of stored product insect pests in stored wheat presents such a diversity of problems that the integration of expertise of persons trained in a number of different professions and skills is required. Programmes primarily reliant on the use of persistent pesticides have proved to be of transient value because of the emergence of pesticide resistance in the target species and the general unacceptability of pesticide contamination of food products.

In Australia, the Wheat Industry has developed an extremely strict attitude to the control of insect infestation. The achievement of the desired standard was made possible by the adoption of malathion as a grain protectant; however, absolute dependence has not been placed on that method. Indeed, the planning of a more contained and durable prevention and control system, has been intensified. Research results and planning have reached the stage at which organization and implementation of the developed integrated programme has commenced.

CONTROL OF INSECT INFESTATION INDUCED BY SOLAR HEATING OF AERATED FARM SILOS

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A farm silo aeration experiment in Victoria indicated that insect development can be controlled provided that grain in adequately cooled near the north-west wall, the region subject to maximum solar heating in the Southern Hemisphere. Wheat sampled after 18 months storage in two aerated silos contained 13 species of insects. One silo was unshaded to the north-west, with aeration ducting remote from that region. Here a *Rhizopertha dominica* F. (Coleoptera) infestation developed, producing heat and dust which retarded cooling. In the other silo which was partially shaded with ducting closer to the north-west wall, there was no localised infestation of *R. dominica.* Cooling the region most affected by solar heating can be improved by positioning of ducts to give airflow bias to the region, by shading, and by coating with reflective paint or insulating. Increasing the average air flow must be limited to avoid undesirable increase in grain moisture content.

THE USE OF NITROGEN FOR INSECT CONTROL IN STORED CEREALS

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The present problems associated with the emergence of pesticide resistance in stored product pests and with residues of toxic chemicals in grain have encouraged further work on the use of inert atmospheres as a control measure.

Small scale field trials involving bins of 5,000 bushel capacity indicated that the establishment and maintenance of low oxygen atmospheres was possible. A trial was then carried out on a large welded steel bin containing more than 250,000 bushels of wheat. The use of tanker nitrogen to purge the oxygen from the wheat was successful and although the bin proved to be leaky the trial enabled an estimate of the cost of purging and maintenance of the necessary atmosphere to be made.

Concurrent investigations were carried out in the laboratory to determine the mortality of many common species of grain pests due to low oxygen atmospheres. A clear temperature dependence, likely to be very important in practice, has been shown.

SECTION NO. 15

TROPICAL ENTOMOLOGY

CONVENOR: T.V. BOURKE

A REVIEW OF THE PEST STATUS OF LEAF-CUTTING ANTS AND THEIR CONTROL

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The distribution of leaf-cutting ants of the genera *Atta* and *Acromyrmex* (Hymenoptera, Formicidae), amongst the most important general pests of growing plants in the New World tropics and sub tropics, is briefly reviewed, together with the types of damage they cause. Estimates of the extent of economic damage are reported, as well as the control methods currently in use.

Data for this review have been obtained both from the literature, and from the results of a questionnaire distributed widely in the countries affected.

FORAGING HABITS OF LEAF-CUTTING ANTS (ATTINAE: FORMICIDAE) IN TRINIDADIAN CITRUS AND COCOA FIELDS

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The amount of vegetation collected by individual nests and diel foraging cycles have been measured using electronic counters placed on natural trials. Food requirements are correlated to the size of nests and the state of brood in the laboratory and field. Medium-sized nests of *Acromyrmex octospinosus* may cut up to 4,000 fragments of young citrus or cocoa leaves per day, and *A. cephalotes* 21,000. The relative preference of *A. octospinosus* for cocoa leaves and flowers is described.

Counts of the density of nests in commercial fields of young citrus and cocoa, and their food requirements, are correlated to the foliage produced by the trees to show how many ants can be tolerated per acre before damage is serious.

Components of the weather and the micro-environment on trials and in nests are analysed and related to the initiation and duration of diel foraging cycles.

AERIAL BAITING TO CONTROL LEAF-CUTTING ANTS (ATTINAE: FORMICIDAE)

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Leaf-cutting ants cause enormous losses to tree crops, timber, vegetables and pasture in Central and South America. They can be controlled more cheaply in some areas by the application of toxic baits from aircraft than by the traditional methods of hand application. Waterproofing the bait prolongs its attractiveness in wet weather. The timing of baiting in relation to the weather and the ants' annual sexual cycle affects the persistence of the bait and the probability of re-infestation by young queens. The extent of baiting depends on the foraging range of species present, and their preferred habitat.

Aerial baiting of a 1,000-acre island with aldrin applied at 3.6 g per acre killed 91% of nests of *Acromyrmex octospinosus* Reich. The opportunity was also taken to study the effects of this programme on wild-life, especially insectivorous lizards and crabs.

It was concluded that large-scale aerial control programmes are feasible, and would result in a decrease in the total amount of insecticide used per acre against leaf-cutting ants compared with present hand application methods.

POLYMORPHISM AND COLONY POPULATION STRUCTURE AMONG TROPICAL ANTS

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The results of a six year survey to determine the size-frequency distribution patterns of workers of tropical ants are presented. The study included two species of primitive fungus-growing ants of the genus *Apterostigma,* five species of leaf-cutting ants of the genera *Atta* and *Acromyrmex,* two species of ponerine ants of the genera *Dinoponera* and *Paraponera,* and four species of army ants of the genus *Eciton.* Size-frequency curves are given for all species studied. These include unimodal, bimodal, and trimodal patterns of distribution. The relationship between polymorphism, population structure, and division of labor is shown for leaf-cutting ants. The allometric basis for polymorphism is demonstrated for two species of army ants. The adaptative significance of the observed size-frequency distribution patterns is discussed, with particular reference to the presence or absence of the "soldier" subcaste.

THE ROLE OF *ANOPLOLEPIS LONGIPES* JERDON (HYMENOPTERA: FORMICIDAE) IN THE ENTOMOLOGY OF CACAO IN THE NORTHERN DISTRICT OF PAPUA NEW GUINEA

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Anoplolepis longipes is a cosmopolitan tramp species of Indo-Malayan origin, now widely distributed in the Melanesian and Pacific regions.

In the Northern District of Papua New Guinea, *A. longipes* has become established in some cacao plantings where it now exerts control over several insect pests.

Control of the cacao weevil borer *Pantorhytes szentivanyi* Marshall is described in trials which show that harassment of *P. szentivanyi* adults by this ant induces dispersion of the pest out of an area newly occupied by the ant, and that whilst occupied, an area is protected from reinfestation by *P. szentivanyi.*

The occupation of cacao by *A. longipes* is unstable and from a series of observations this instability is attributed to fluctuations in numbers of honeydew-producers whose secretions are a major source of food for the ant. It was found that honeydew-producer numbers are dependent on the availability of suitable feeding sites on the cacao tree, the availability of which is seasonal.

FIELD STUDIES IN THE USE OF THE *OECOPHYLLA* ANT IN THE CONTROL OF PREMATURE NUTFALL IN COCONUTS IN THE SOLOMON ISLANDS

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In the Solomon Islands premature nutfall in coconuts is caused by the coreid bug *Amblypelta cocophaga* China. Feeding by *Amblypelta* adults and nymphs on young nuts causes them to fall between the 4th and 8th week. The presence or absence of *Amblypelta*-produced nutfall is related to the species of ant inhabiting the coconut palms. Where *Oecophylla smaragdina* F. inhabits the palms *Amblypelta* are driven out and no nutfall occurs. Unfortunately the distribution of *Oecophylla* within a plantation is influenced by antagonistic ants particularly *Pheidole megacephala* F. a small soil-nesting species which also makes nests at the base of the palm among adventitious roots. Where this ant occurs *Oecophylla* cannot colonise the palms and *Amblypelta* feeds unmolested in the crowns causing severe nutfall so that often over 80% of the palms are completely barren.

The problem resolves itself into the elimination of *Pheidole* and the encouragement of *Oecophylla*. In field trials, *Pheidole* has been eliminated by herbicidal ring weeding of palms followed by 3 applications of dieldrin insecticide to the palm base. The spread of *Oecophylla* in treated areas occurs naturally provided the vegetation is kept down to low herbage with creepers.

Where the number of palms inhabited by *Oecophylla* in a plantation suffering from nutfall is low (< 5%) it is necessary to introduce the ant artificially. This can be accomplished by utilising an intermediate tree which both supports pseudococcids and can be easily grown. The tree most suitable for this purpose is the soursop *(Anona muricata)*. Nests of *Oecophylla* can be placed in these trees and the ant allowed to construct new nests. In due course, the *Oecophylla* will spread onto the coconuts and then gradually throughout the plantation.

ANTS IN RELATION TO DAMAGE IN WEST AFRICAN COCOA FARMS CAUSED BY THE CAPSIDS *DISTANTIELLA THEOBROMA* (DIST.) AND *SAHLBERGELLA SINGULARIS* HAGL. (HEM. MIRIDAE)

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An analysis of samples of 100 individual trees from each of 64 farm cocoa plots in Ghana showed that both *Oecophylla longinoda* Latr. and *Macromischoides aculeatus* (Mayr) were significantly negatively associated with fresh capsid damage. Other dominant ant species were either weakly negatively associated, or as in the case of the majority of *Crematogaster* species, positively associated with damage i.e. protective of capsids. A further analysis showed that the nett effect of 16.5% reduction in capsid damage was attributable to an ant-negative association with *D. theobroma* but not with *S. singularis*.

From a large number of samples using both pyrethrum knockdown and direct tree trunk counting on farm plots scattered throughout the cocoa growing area of Ghana, and using the relativities derived from the first exercise, it could be calculated that the mean capsid reducing effect of the presence of ants, mainly *Oecophylla* and *Macromischoides* was 15%. Therefore, on average over 80% of Ghana cocoa was not protected from capsid injury by ants.

THE ANT MOSAIC: A BASIC PROPERTY OF THE TROPICAL FOREST ZONE

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Evidence is given from surveys in Ghana which, with published observations, indicate that tropical ecosystems carry a mosaic of dominant ants. In Ghana about fifteen dominant species fill almost all available space and in forest the mosaic is three-dimensional. The identity of the dominant at any place determines the nature, in species and abundance, of most of the arthropod fauna, especially the arboreal and terrestrial components. Through their effect upon leaf- or seed-feeding insects, pollinators and/or dispersing agents, vectors (usually homopters) of plant pathogens, etc., ants play a part second only to abiotic factors in influencing vegetation.

The agricultural implications are immense: the distribution of positively and negatively associated dominants mediates the dispersion of plant pests. Control through cultivational methods which manipulate the mosaic in favour of the beneficial dominant, that associated with the least harmful pest spectrum, and limiting to the malevolent, is envisaged.

INTERACTIONS BETWEEN ANT SPECIES AND THE COMPOSITION OF TROPICAL ANT FAUNAS

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Ants are important on some tree crops in the tropics, both as beneficial and noxious insects, according to whether they prevent or allow attack by pests. There is scope for manipulation of local associations of ants so that beneficial species predominate and this requires knowledge of the factors controlling the composition of faunas. They are strongly influenced by vegetation through its effects on nutritional, climatic and structural aspects of habitat. These factors provide a conditioned framework within which interactions between species are highly significant.

In lowland forest these interactions play a major part in the stratification of arboreal, epigaeic and cryptic groups of species. Within the first two categories at least, dominance series can be recognised in which successive species can displace or inhibit inferior competitors. The presence of a species high in the order of dominance may enhance species diversity by preventing monopoly of resources by one or a few pervasive, middle order species, at the same time coexisting with a greater number of species that are, individually, inferior competitors.

In habitats other than lowland forest the numbers of species in local faunas are reduced, particularly epigaeic species with small foraging areas. Related to this, horizontal stratification is relaxed and relatively specialised forest species tend to be replaced by fewer, more widely adapted, and more geographically widespread species. Data from Australia and the Solomon Islands are used to illustrate these points.

A RATIONAL APPROACH TO CONTROL BY ANTS OF PEST SITUATIONS IN TROPICAL TREE CROPS

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More successes than failures have been reported in the literature of attempts at manipulation of ants for pest control in tropical tree crops. Hence, the concept of this kind of control is of more than academic interest, and it is from this standpoint that an approach is suggested to the evaluation and development of ant induced control in such a crop.

A series of stages comprising definition of the pest problem, selection of a candidate ant species, development of techniques for manipulation of the ant, and estimation of the economic viability of a feasible control scheme are put forward.

The most difficult part of such a programme is the development of methods for establishing and maintaining large populations of the useful ant in the crop. The reasons for this vary from case to case, but some examples are the lack of an economic means of reducing competition from non-beneficial ant species; seasonal changes in ant food supply and demand; and incompatibility between a healthy crop and the conditions necessary for high worker production by the ant.

BIONOMICS OF *ENTYPOTRACHELUS MYERI* KOLBE AND *E. MICANS* HUSTACHE (COLEOPTERA: CURCULIONIDAE) INDIGENOUS FOREST WEEVILS ASSOCIATED WITH TEA IN KENYA

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The weevil genus *Entypotrachelus* Kolbe is reported to be indigenous exclusively to Kenya and Tanzania; eight species and two subspecies are known. *E. meyeri* Kolbe occurs in northern Tanzania in the vicinity of Mt. Kilimanjaro and also west of the Great Rift Valley in the tea gardens near Kericho, Kenya. *E. meyeri micans* occurs east of the Rift in the foot-hills of Mt. Kenya. Adults of both species defoliate trees, woody shrubs and weeds in the Montane Rain Forest.

When the forest is cleared, *E. meyeri* adults severely defoliate newly established tea and the quinine tree *(Cinchona)*. *E. meyeri micans* larvae destroy the taproot of nursery-grown tea seedlings; adults defoliate seedlings and vegetatively propagated tea in nurseries and gardens.

Research conducted from 1965 to 1968 into the bionomics, biology, adult feeding behavior, rate of leaf destruction, migration and interval survival rate of both weevils is summarized.

POPULATION FLUCTUATIONS OF THE COCOA MIRID IN THE NORTHERN DISTRICT OF PAPUA NEW GUINEA

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Helopeltis clavifer (Walker) (Heteroptera: Miridae), an indigenous mirid of the Subfamily Bryocorinae, has been recorded on native *Ficus* spp. and the introduced species sweet potato *(Ipomoea batatas)*, tea *(Camellia sinensis)* and cacao *(Theobroma cacao)*. Over the past 8-10 years it has developed into a serious pest of cacao in the Northern District of Papua New Guinea. Factors responsible are thought to be the very short generation time of 23-24 days, and the particularly favourable environment and food source (cacao) available in the cacao monoculture.

This paper discusses some of the factors which influence *H. clavifer* population fluctuations.

Records over the past 30 months have shown that meteorological rather than biotic factors are more important in regulating *Helopeltis* numbers. An extended dry season promotes massive population increases, which continue until heavy rain (of the order of 2,500 - 4,000 mm per month) falls and the populations crash. Probable reasons for these crashes are discussed.

Pod production, vegetative flush production, predators and parasites have very little effect on population levels.

The effect of shade species and level of shade was also studied. *Helopeltis* numbers were high on cacao grown under low shade *(Leucaena leucocephala)*, medium on trees without shade and low and of little economic importance on cacao under high shade (coconuts, rubber or thinned primary bush).

OBSERVATIONS ON DYNASTID BEETLES ATTACKING COCONUT PALMS IN THE NEW GUINEA REGION

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In the New Guinea region two dynastid beetles attack palms, an introduced species *Oryctes rhinoceros* L. and an endemic species *Scapanes australis* Sternb. (4 subspecies). *Oryctes* occurs in West Irian, Manus Island, New Ireland and New Britain, but is absent from Papua and the East New Guinea mainland, Bougainville and the Solomons. *Scapanes* is endemic through the whole area.

In areas where the two species overlap there is no competition between them as they feed on different age groups of palms and have different requirements for breeding sites. Also the life cycle of *Scapanes* is much longer than that of *Oryctes*. Both species are little affected by natural parasitism, predation or disease. The main factor affecting their abundance appears to be the number and availability of suitable breeding sites.

Five other endemic species of dynastids may be associated with *Oryctes* or *Scapanes* in breeding sites or as minor pests of palms.

THE EFFECT OF PEST DAMAGE ON OIL PALM PRODUCTION

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An attempt is made to provide an objective assessment of the correlation between pest damage in the oil palm and yield loss. This type of information is scarce for most crops, particularly perennial crops in the tropics or where damage does not directly affect the commercial part of the plant. Its importance to pest management strategy is discussed.

Leaf-eating caterpillar damage was simulated by removal of leaf tissue at various intensities and the effect on cropping was studied.

Rhinoceros beetle *(Oryctes rhinoceros)* caused heavy damage to young palms in a bare-ground plot, before fruiting. Early yield was compared in this and an adjacent unaffected plot.

Root-eating cockchafers *(Psilopholis vestita)* attacked palms and a replicated trial on possible control measures was carried out. Differential success led to plots of presumed differing degree of damage. Subsequent growth and yield performance is compared.

THE IMPACT OF SUPPLEMENTARY CROP IRRIGATION ON PEST ABUNDANCE IN A DRY TROPICAL ENVIRONMENT

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North Australia is characterised by a hot wet season and a cool then very hot dry season. In this climate a savannah woodland or open savannah grassland is the dominant vegetation.

Under undisturbed conditions severe restraints are imposed on abundance of phytophagous insects unless they possess a diapausal mechanism for surviving the dry season. Such insects are generally restricted in host range.

Other insects survive in absence of a dry season resting stage, but are generally inconspicuous except in periods of heavy or unseasonal rainfall. These insects survive by possessing a wide host range, good powers of flight and ability to detect suitable vegetation together with very high potential fecundity in order to exploit suitable conditions.

Supplementary crop irrigation increases food supply and prolongs its availability. Non-diapausing insects are able to exploit these conditions while diapausing insects are unable to respond to them, the former then becoming dominant pests. Implications of the above principles for the most desirable methods of pest management will be discussed.

METHODOLOGY OF CAPSID SPRAY TRIALS ON COCOA FARMS IN GHANA

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Farm cocoa stands in Ghana vary in tree number, size, condition and degree of pest damage. The main pest species are the mirids *Distantiella theobroma* (Dist.) and *Sahlbergella singularis* Hgl. (Hemiptera, Miridae). Both species vary widely in number per tree and per season. Trial methods were developed using small plots for ease of management, spraying, sampling and recording and to reduce error components in statistical analyses.

Plots, standardised at 0.4 ha and selected for uniformity of damage were grouped into site blocks of comparable condition. Treatments, randomised within each block, were replicated on at least seven sites to allow for extreme departure from mean values in 20% of the plots.

Spraying procedure was uniform and the outside 4 m perimeter was also sprayed to reduce plot reinfestation. All plot trees were recorded at prescribed times for canopy condition, pod number and number of trees infested with live capsids as minimal criteria. Additional data for insect population changes and interactions as required were recorded from 100 sample trees per plot.

RECENT ADVANCES IN THE INSECTICIDAL CONTROL OF COCOA MIRIDS IN GHANA

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Cocoa mirids, *Distantiella theobroma* (Dist.) and *Sahlbergella singularis* Hagl. are major pests of cocoa in Ghana. Since the beginning of the century, various methods of chemical control have been used with firstly nicotine sulphate, then DDT and recently lindane being the insecticide of choice.

The continuing programme of screening candidate insecticides, mainly carbamates and organophosphates was intensified in early 1962 when some populations of mirids were found to be resistant to lindane and the other chlorinated hydrocarbon insecticides.

Results obtained suggest that the carbamates arprocarb at 2 oz, Ortho-bux at 4 oz and lindane/arprocarb mixture (2:1) at 3 oz active ingredient in 5 gallons of water per acre are the most promising alternatives to lindane for mirid control.

For the control of mirids and other minor pests of young cocoa, 0.43 mg per tree of the systemic organophosphate monocrotophos, when painted on the stem has proved effective.

The side effects of those insecticides are discussed.

A VENTILATED PROTECTIVE SUIT FOR USE WITH A BACK MOUNTED MISTBLOWER IN THE TROPICS

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Inadequate penetration of dense foliage often makes aerial application of insecticides against pests feeding on leaves near the base of big tobacco plants ineffective. A better distribution of spray particles is achieved with back mounted manual mistblowers fitted with flattened mesh diffusers. When toxic materials are applied with such a machine, the protective clothing necessary for safe operation is extremely tedious to wear, particularly in the tropics.

We have designed an impermeable PVC garment ventilated by a stream of filtered air from the mistblower that does not affect the efficiency of the machine, and allows the operator to work in safety and comparative comfort. The air pressure inside the suit prevents accidental contamination through tears and ventilator holes and the flow of air out of the suit near the head, helps to prevent toxic particles impinging on the face.

EFFECT OF DIMECRON 100 ULTRA-LOW-VOLUME (ULV) AERIAL APPLICATION ON RICE OVER A LARGE AREA IN JAVA

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Rice stem borers *Tryporyza incertulas* Walk. and *Tryporyza innotata* (Walk.) are serious pests of rice in Indonesia and are responsible for major losses of rice crop especially in the islands of Java and Sulawesi. During 1968 to 1970, CIBA undertook a project under BIMAS GOTONG ROJONG for the control of rice stem borer over a large area in Java. Dimecron 100^R was applied as ultra-low-volume (ULV) by Pilatus Porter aeroplane. During 1969 to 1970, a study was undertaken jointly by students from Padjadjaran University, Faculty of Agriculture, Bandung; the Agriculture Extension Service, Ministry of Agriculture, Indonesia, and CIBA Ltd. to find out the effect of aerial application of Dimecron 100^R in terms of rice yield and also its effect on stem borer populations. The results obtained indicate a significant increase in rice yield and also a significant reduction of rice stem borer population in the aerially treated areas.

FUNDAMENTALS OF TROPICAL INSECT PHENOLOGY

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The phenology of over 80 species of Ghanaian insects falls into a limited number of periodic patterns tied directly or indirectly to the phenomena of flushing, flowering and fruiting of food plants. No single climatic parameter delimits the seasons deduced from the data but a combination of mean monthly rainfall and mean monthly hours of bright sunshine per day fits the observations. A new type of climograph is introduced.

The seasons in the Ghana forest zone are: dry sunny, 1st wet sunny, 1st wet dull, dry dull, 2nd wet dull, 2nd wet sunny. Elucidation has enabled predictions of entomological events to be made. The savanna zone has a different seasonal pattern but the same parameters apply.

The proposed method of defining seasons should have widespread use in tropical insect studies but lack of published sunshine figures has to date prevented extension of the scheme outside West Africa.

LIFE HISTORIES OF PSOCOPTERA IN THE MATO GROSSO, CENTRAL BRAZIL

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Regular sampling during 1968-69 in central Brazil elucidated the life histories of nearly 90 species of Psocoptera.

The life histories are of two basic types:

1. Seasonal species, which undergo 1-3 discrete generations through part of each year.
2. Species that breed continuously. These are sometimes difficult to distinguish from seasonal species, and may give the appearance of having discrete generations in that (a) many Psocidae lay large egg batches. Synchronised hatching and nymphal aggregation may result in >40 individuals of similar age in one sample; (b) some Pachytroctidae colonise dead foliage at any time of the year. Availability of such suitable microhabitats influences superficial appearance of populations of uniform age; and (c) relative abundance of Psocoptera in different litter types is affected by seasonal climatic factors. Seasonal rain results in sodden forest litter, and psocids are then relatively more numerous in better drained savannah litter: continuously-brooded species may then be virtually absent from forest litter.

Such cases indicate that Psocopteran life histories in the tropics may be difficult to interpret unless sufficient samples are taken over a wide area.

DISTRIBUTION PATTERNS AND SPECIES DIVERSITY IN THE MICROLEPIDOPTEROUS FAMILY STENOMIDAE (LEPIDOPTERA: GELECHIOIDEA)

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In terms of species numbers and diversity the family Stenomidae is the largest and most characteristic element of the Microlepidoptera fauna of the Neotropical Region. Essentially tropical in distribution throughout its range, the family has achieved remarkable diversity in Central and South America where hundreds of species occur in a broad range of habitats. Examination of distribution patterns within the family suggestsseveral possible explanations for the notable diversity attained in the New World tropics and these are presented along with correlated biological data. In addition, recent studies of Old World tropical elements of the family suggest that the stenomids originated in the Indo-Australian Region and entered the New World via a southern route.

INSECT DIVERSITY IN NIGERIA

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Approximately 8,000 genera of insects are recorded in West Africa south of the Sahara. About 90 per cent of these genera are known in Nigeria, either from the literature or in collections made by the writer. The Nigerian fauna is greatly diverse. An analysis of similar faunal elements in other parts of tropical Africa suggests that several distribution pathways and/or barriers existed in historical times. At both the generic and specific levels two conspicuous faunal elements are recognized: one associated with the great tropical rain forest of central Africa, the other represented in the broad savannah lying between the rain forest and the Sahara. Of particular interest are faunal similarities between East and West Africa which can be demonstrated in certain groups collected at higher elevations in Nigeria. One explanation for this may be interconnection of the montane islands prior to changes in the African climate about 7,000 years ago.

DIVERSITY IN FORM AND COLOUR IN SOME CENTRAL AFRICAN ACRIDOIDS, AND ASSOCIATED PHENOMENA

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Form in the Acridoidea of Central Africa may be associated with habitat as for example the slender, grass-like *Acrida* spp. Its habit of lying along grass-stems and keeping on the opposite side from intruders may give some protection against predation. Cryptic form in some species is associated with flash coloration, and this may be further enhanced by crepitation as in *Acrida sulphuripennis* Gerst. Similar behaviour is shown by some ground dwellers including *Morphacris fasciata* Thunb. Extreme cryptic coloration is shown by *Tmetanota terrosa* Sauss. Tree-dwellers may be bark-like and adapted to fit closely to branches (e.g. *Mecostibus* spp.).

Many species show predominantly brown or green colour forms and these are often associated with seasonal vegetational changes. Warning coloration is found in many evidently distasteful species, especially Pyrgomorphidae. *Taphronota cincta* (Burm.) shows incipient phase differentiation. Solitarious hoppers are green but gregarious ones black and bright yellow, as are the invariably gregarious hoppers of *Phymateus baccatus* Stål and *Zonocerus elegans* (Thunb.).

Great variation in wing size is found, not only between species, but sometimes within species, e.g. *Chrotogonus hemipterus* Schaum and *Zonocerus elegans*. In Pamphagidae-Porthetinae it is a regular sexual difference.

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CLOSING PLENARY SESSION

Address by Professor J.S. Kennedy
Imperial College Field Station, Silwood Park, Ascot, Berks., England

THE EMERGENCE OF BEHAVIOUR

A notable feature of contemporary entomology is the emergence of the study of insect behaviour as an independent discipline with its own contribution to make to the neighbouring disciplines of physiology on the one side and ecology, pure and applied, on the other. By long tradition it has also a third link, through anthropomorphism, with psychology and this continues to give trouble in both the physiological and ecological contexts. But behaviour is already contributing to neurophysiology, and *vice versa*, especially at the level of particular, given responses where the behaviour itself is regarded physiologically, and this is opening the door to neurophysiological analysis of more complex behavioural interactions. Behaviour studies are also helping to change the content of some general ecological concepts such as adaptation, migration and intraspecific competition, where the existing, somewhat mechanistic models are giving way to more sophisticatedly adaptive biological ones. In applied ecology, pest control, behaviour has become a major focus of interest and it may be hoped that the sophistication here will not always remain so largely on the chemical side.

LIBRARY U. OF I. URBANA-CHAMPAIGN

FILM AND SLIDE SUMMARIES

ORGANIZER: R.W. TAYLOR

OVIPOSITION IN SOME CRANE-FLIES (TIPULIDAE)

A.M. Hemmingsen

(Black and white, silent, 7 min)

Superficial ovipositions of *Tipula (Tipula) paludosa* Meigen, 1830, and deep-boring ovipositions of *Tipula (Vestiplex) scripta* Meigen, 1830 and *Tipula (Odonatisca) juncea* Meigen, 1818.

INSTINCTS OF IMMATURE AND ADULT VERMILEONINAE (DIPTERA: BRACYCERA: RHAGIONIDAE)

A.M. Hemmingsen

(Black and white, silent, 20 min)

Larval and pupal instincts of vermileonine larvae (worm-lions). Feeding and mating instincts of adults, and specific ovipository instincts of two Canarian species, *Lampromyia canariensis* Macquart, 1838 and *Lampromyia fortunata* Stuckenberg, 1971.

COMPORTEMENTS INTERINDIVIDUELS CHEZ *BLABERA CRANIIFER* (BURM)

G. Richard

(Black and white, sound, 15 min)

The first part of the film concerns the sexual behaviour: attraction of male by female, exchanges of stimulations between male and female, the stages of courtship by the male, and responses of the female to the male displays. Evolution of the behaviour of female in relation to their internal state, virgin unreceptive female, female after mating and pregnant female.

The second part of the film concerns the behaviour between male. Unfolding behavioural sequences leading to a dominance - subordination state; behaviour of dominant male and submissive male - releasing of homosexual behaviour.

"BULL ANT WARRIORS: AN EXPERIMENTAL STUDY OF AGGRESSIVE BEHAVIOUR"

P.L. Robertson and C.J. Orton

(Colour, sound, 25 min)

The film is based on biological aspects of a combined chemical and biological research project on "Insect Venoms, Attractants and Repellents". It demonstrates techniques developed and results achieved in an experimental study of aggressive behaviour in the primitive Australian Bull Ant, *Myrmecia gulosa*. The species is one in which both solitary and social elements of aggressive behaviour are displayed.

Shots of fighting in the field are followed by close-ups analysing stinging behaviour in the laboratory. Demonstrations are made of the glandular origin and physical properties of the venom injected into the prey as a killing agent. Dissection techniques, and behavioural experiments based on artificial prey, are used to show that not only is venom secreted during stinging, but also a complex of chemical signals stimulating aggressive behaviour in other members of the same nest.

AN HYPOTHESIS ON THE EFFECT OF ATMOSPHERIC SMALL AIR IONS AND WEATHER FRONTS ON THE EMERGENCE OF *WISEANA CERVINATA* (LEPIDOPTERA)

G.A.H. Helson

(Black and white, sound, 8 min)

Porina moths (*Wiseana* spp.) in New Zealand show flight activity, 15 to 30 hr before the approach of low pressure cold fronts with rain or mist. An hypothesis to explain this is that variations in the ratios of positive to negative atmospheric small ions, might be the dynamic stimulus triggering moth-emergence in spring and early summer. Continuous measurements were made of small ion concentrations during passage of weather fronts over Wellington. Simultaneously, daily insect biomass from an adjacent light trap was collated with moth flight records at other trapping stations. A possible correlation between flight activity of the moths, and the passage of cold fronts and associated variations in atmospheric small ion ratios has been noticed.

COMPARATIVE NESTING BEHAVIOUR OF AUSTRALIAN *BEMBIX* WASPS (HYMENOPTERA: SPHECIDAE)

H.E. Evans and R.W. Matthews

(Colour, sound, 30 min)

Significant comparisons of nesting behaviour in Australian *Bembix* sand wasps are made. Three relatively large, generalized south-eastern species are compared, then one from coastal dunes in Western Australia. Six smaller species of more specialized behaviour are then considered. Several of these nest together in the dry interior. They differ in such matters as nest closure, mode of soil dispersal at the nest entrance, type of prey, and manner of oviposition. All ten species are compared with respect to these behavioural features. They are much more distinctive in behaviour than in structure of colour.

INSECT TISSUE CULTURE

CSIRO

(Colour, 16 min)

Techniques for the tissue culture of cells from insects are shown and various features of the growth of the cells analysed, before and after infection with a polyhedral virus disease.

SWARMING FLIES

P. Belton

(Colour, sound, 10 min)

SWIRLING SAFEGUARD

J. Ardley

(20 min)

HER HOME IS A HOLE, THE STORY OF THE ALFALFA LEAFCUTTER BEE

E.C. Klostermeyer and H.S. Gerber

(Colour, sound, 13 min)

A general education film describing the use of the alfalfa leafcutter bee *(Megachile rotundata)* for alfalfa pollination. It features close-up pictures of the bee constructing nests in transparent tubes. Provisioning and oviposition is shown in cells with the leaf lining removed. The oviposition sequences are particularly interesting and show the difference in oviposition of male and female eggs. Leaf cutting and pollen collecting are described and pictured.

THE DEATH WATCH BEETLE

S.A. Richardson

(Colour, sound, 14 min)

Records life-cycle of *Xestobium rufovillosum*, de Geer, commencing with emergence from oak which has been attacked by *Merulius lacrymans;* abortive efforts of imago to fly; the characteristic tapping; the unusual copulation, ovipositing, larval penetration, progress of larvae into vessels and creation of galleries; explanation of long period spent by larvae in wood; excavation of pupal chamber; development of pupa and final metamorphosis: the whole cycle covering a period of about ten years.

LIFE CYCLE OF THE MONARCH BUTTERFLY

L.D. Anderson

(Film produced by K. Middleham, L.D. Anderson and B. Moore)

(Colour, sound, 11 min)

"Life Cycle of the Monarch" is a detailed study of the four life stages of this typical and common butterfly. Close-up photography allows the observance of details of the hatching of the egg, molting of the larva, formation of the pupa, and emergence of the adult butterfly. As particular structures appear during these stages they are examined in detail by means of high magnification and time-lapse photography. The microscope is utilized to show details of the butterfly wing and scales.

THE GUARDIAN

R.W. Sherman

(A 1972 Production of the Animal and Plant Health Service of the United States Department of Agriculture)

(Colour, sound, 28 min)

The film shows how U.S. Department of Agriculture Inspectors at ports of entry, along with specialists in the field and entomologists and plant pathologists in laboratories, guard United States' farms, gardens and forests against the introduction of hazardous plant pests.

INSECTS VERSUS ALLIGATOR WEED

R.I. Sailer

(Colour, sound, 18 min)

A flea beetle introduced from Argentina is eliminating Alligator weed as a problem in waterways of Florida and other coastal areas of the southeastern United States.

RADAR ENTOMOLOGY

G.W. Schaeffer

(Colour, 20 min)

This film records the techniques and results of using simple radars to study insect migration and associated meteorology. Time-lapse sequences illustrate the flight activity of individuals in three dimensions, the influence of wind fields and the dramatic effects of wind convergence (convection cells, squall lines, low level jet streams, Inter-Tropical Front) on aerial density and insect transportation. The remarkable orientation of noctural migrants and the identification of individual species and sex at distances up to 3km are illustrated.

COLONY FOUNDING IN THE ANT GENUS *MANICA* IN A MANNER LIKE THAT OF THE AUSTRALIAN *MYRMECIA*

G. Le Masne

(Colour, sound, 15 min)

AEDES RESEARCH IN EAST AFRICA (1970)

G.A.H. McClelland

(Colour, narrated, 40 min)

Covers research on mosquito biology at the *Aedes* Research Unit, Dar es Salaam, Tanzania. Opens with scenes of WHO AFRO headquarters at Brazzaville and Dar es Salaam. Routine insectary procedures are followed by sequences of field surveys in Tanzania and Kenya, and the identification of material. Emphasis is on biology of *A. aegypti* and *A. simpsoni*. Egg and larval sampling techniques in a coral rock habitat are followed by adult sampling techniques and preparation of mosquito pools for subsequent virus isolation. Resting mosquitoes are caught and processed for blood meal identification. Strain differences in host preference are demonstrated with an olfactometer. The unique biology of *A. woodi* is shown. Methods of estimating absolute densities of mosquitoes are illustrated by drop net and mark-release-recapture techniques. The film concludes with a note on genetic studies of *A. aegypti*.

SOME CURRENT RESEARCH ACTIVITIES IN THE DIVISION OF ENTOMOLOGY

(Colour, 23 min)

Shows successful culture of insect cells, using ovary tissue from Emperor Gum Moth pupa; biological control of the Queensland Fruit Fly and the Green Vegetable Bug by imported parasitic wasps; life history studies of the Cattle Tick leading to more efficient control by spraying; and investigation of Termite behaviour.

THE TERMITE COLONY

(Colour, 33 min)

Termites are much lower in the evolutionary scale than ants and bees, and yet they have developed a remarkable social organization.

All termites live in colonies; some colonies contain millions of individuals. The mutual co-operation that is the basis of these organized societies compensates for the termite's weakness as a single insect, and so the colony becomes an efficient, destructive force.

This film takes a close look at the social behaviour of several termite species, and shows that the very strength of the colony - the dependence of each individual on the community as a whole - could be its greatest weakness, when it comes to devising control measures.

EMBRYONIC DEVELOPMENT OF THE LIGHT BROWN APPLE MOTH

(18 min)

The egg of this insect was found particularly suitable for observation of embryonic development. A complete record was made by time-lapse cinemicrography at one frame each 32 seconds, covering an egg from the blastoderm stage four hours after fertilisation when processes became visible, to the hatching of the larva.

THE BIOLOGICAL CONTROL OF INSECTS

(Colour, 36 min)

Spraying insect pests with insecticides is not the only way to control them.

This film shows a number of pests in close-up in the laboratory - the Cottony Cushion Scale, the Cabbage Moth, the Cabbage White Butterfly, the Green Vegetable Bug, and the Vegetable Weevil. After outlining the success with which they have been controlled by their natural enemies, the film explores the entomologists' search for a wasp to control the Queensland Fruit Fly.

An example of the use of virus diseases as another biological control measure is also shown.

DUNG DOWN UNDER

CSIRO

(Colour, sound, 16 min)

NEW GUINEA

(Kindly provided by the Department of External Territories)

(Colour, sound, 44 min)

SUCCESSION OF INSECT COMMUNITIES IN THE BERNINA GLACIER REGION, SWITZERLAND

M.B. Kiauta

INSECT FALLOUT ON SNOWFIELDS

J.S. Edwards

The insect fauna of snow fields can be divided into two elements: the true nival insects which are adapted to life on the snow as scavengers and predators, dependent on the second element, the adventitious "fallout." The source, mechanisms of capture on the snow surfaces, and the fate of the fallout insect fauna will be presented.

THE SPECIES ABUNDANCE DISTRIBUTION IN STABLE AND UNSTABLE COMMUNITIES OF INSECTS

S.J.R. Birket-Smith

Samples of up to 2400 specimens of 460 species of insects from Disturbed and Undisturbed areas in Nigeria and Ethiopia are analysed by electronic data processing, and the resulting distributions shown. Since these do not agree very well with older models a new one is proposed on a purely empirical base.

AIRCRAFT DISINSECTION - ITS HISTORY, STATUS, AND FUTURE

M. Laird and W.N. Sullivan Jr.

(36 slides, 30 min)

Both speakers will mention certain historical aspects of aircraft disinsection, Mr. Sullivan concentrating on agricultural issues and Dr. Laird on past establishments of insects of public health importance following accidental importation by aircraft. Dr. Laird will devote the greater part of his presentation to the events that lead up to the introduction of the "blocks away" methodology through the recommendations of the 11th session of WHO's Expert Committee on Insecticides (Geneva, 1961). Mr. Sullivan will concentrate on relevant research that has subsequently taken place with particular attention to improved means of killing insects accidentally present on board aircraft, and to an assessment of the present feasibility of achieving this end through in-the-air spraying featuring built-in equipment and vapour pressure insecticides. He will bring the account up-to-date on the basis of experience gained during WHO-supported experiments involving tests during long distance flights in 1971.

INTEGRATED MOSQUITO CONTROL IN TROPICAL ISLANDS

M.C.E. Giglioli

The presentation will illustrate buildup of a mosquito control programme, progressing through physical control by water management, to application of insecticides by fogging machines and aircraft, and studies on biological control with minnows. Logistics of operations in small tropical islands will be emphasised, including selection of equipment and techniques which are complimentary, and maintenance problems. The purpose of the slide programme is to illustrate practical problems encountered and solved. Scientific results will not be emphasised.

AUSTRALIAN INJURIOUS ARTHROPODS

R.V. Southcott

A series of slides of arthropods which bite, sting, irritate or molest man in Australia and New Guinea, and their effects. The programme supplements the Author's paper, giving more extended photographic treatment of the subject.

Centipedes, millipedes, scorpions, mites, spiders and insects (thrips, Hymenoptera, biting Diptera, urticating and stinging caterpillars and their subsequent instars, Hemiptera, etc.) are included.

INSECT ADAPTATION TO A TROPICAL RAIN FOREST ENVIRONMENT: THE NESTING HABITS OF EUGLOSSINE BEES

D. Dias

The Euglossine bees are the Apidae least known biologically. The presentation will show ecological aspects of the most exhaustive search undertaken to date to locate nesting sites of this important group of neotropical bees. Slides will show: 1. The study area, swamp forest outside Belem, at the Guama River mouth in Northern Brazil; 2. The major types of nesting sites; 3. Structure of nests. Emphasis will be given to adaptative significance of nesting sites, building materials, and interrelations between the bees and several components of the forest environment.

SOME TYPICAL LERPS OF AUSTRALIAN PSYLLIDAE

K.L. Taylor

In several genera of sub-family Spondyliaspinae (Psyllidae), which feed on *Eucalyptus* spp. the nymph constructs a waxy test or lerp, on leaves or twigs. This is built from liquid excrement which rapidly solidifies. Many species can be identified by their lerps which range from simple shell-like forms to intricately woven basket-like structures.

STEREO SCANNING ELECTRON MICROSCOPY OF INSECTS

B.K. Filshie and C.D. Beaton

(30 slides, 15 min)

Best utilization of the enormous depth of focus of the scanning microscope is achieved when micrographs are recorded as stereo pairs. Two micrographs are made, the specimen being tilted a few degrees between exposures. The programme will demonstrate projection of these pairs of micrographs using polarized light, so that a very realistic impression of 3-dimensional structure of insect specimens is achieved.

SEMI-AUTOMATIC FACTORY REARING OF MEDITERRANEAN FRUIT FLY

J. Monro

LEPIDOPTERAN LEAF MINES OF THE FAMILY NEPTICULIDAE/STIGMELLIDAE, WITH NOTES ON THEIR BIOLOGY IN CANADA

C. Wilkinson

(Slides of leaf damage and biological notes on larvae infesting forest and fruit trees)

MORPHOGENESE DE LA RAPE STRIDULANTE D'UN ORTHOPTERE ACRIDIDAE

J.C. Lefeuvre

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